FINAL

PHASE II FEASIBILITY STUDY

Maryland Sand, Gravel and Stone Site
Elkton, Maryland

DAMES & MOORE

7101 Wisconsin Avenue, Suite 700, Bethesda, Maryland 20814

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Maryland Sand, Gravel and Stone
Site
Elkton, Maryland

On behalf of the MSGS PRP's, enclosed are 8 copies (Mr. Peter Ludzia) and 4 copies (Mr. David Healy) of the Final Phase II FS report for the Maryland Sand, Gravel and Stone site. This FS has been updated from the January 9, 1989 draft final report to reflect the MSGS PRP's response to USEPA's March 14, 1989 comments on that report. Data and conclusions from the December 2, 1988 Draft Final Phase II RI and Draft Revised RI sections of March 6 and 20, 1989 were also used in preparing this report.

Yours very truly,

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LIST OF ACRONYMS

ARAR	Applicable or relevant and appropriate requirement
BOD	Biochemical oxygen demand
COD	Chemical oxygen demand
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CLP	Contract Laboratory Program
EA	Endangerment Assessment
EEA	Eastern Excavated Area
FS	Feasibility Study
GAC	Granular activated carbon
gpm	gallons per minute
HI	Hazard Index
MSGS	Maryland Sand, Gravel and Stone
MCL	Maximum contaminant level
MCLG	Maximum contaminant level goal
msl	mean sea level
NCP	National Contingency Plan
NPDES	National Pollutant Discharge Elimination System
O&M	Operation and maintenance
PCB	Polychlorinated biphenyl
ppm	parts per million
PRP	Potentially responsible party
RMCL	Recommended maximum contaminant level
ROD	Record of Decision
RI	Remedial Investigation
RCRA	Resource Conservation and Recovery Act
SARA	Superfund Amendments and Reauthorization Act
TAL	Target Analyte List
TCA	Trichloroethane
TCL	Target Compound List
TOC	Total organic carbon
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
VOC	Volatile organic compound
WEA	Western Excavated Area

SUMMARY

The purpose of a Feasibility Study (FS) is to identify and evaluate a range of remedial alternatives for a site containing hazardous substances as required by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), the Superfund Amendments and Reauthorization Act (SARA), and the National Contingency Plan (NCP). This FS has been prepared by Dames & Moore under the technical direction of the settling MSGS potentially responsible parties (PRP). It recommends what is considered by the settling PRP's to be the remedial alternative that most effectively mitigates and minimizes threats to and provides adequate protection of public health and welfare and the environment, considering technical feasibility, environmental and public health impacts, regulatory aspects, and cost. This final Phase II Report for the Maryland Sand, Gravel and Stone (MSGS) site builds upon a Phase I Remedial Investigation (RI) and FS conducted in 1985 by a U.S. Environmental Protection Agency (USEPA) contractor, a draft final Phase II RI for the site prepared by Dames & Moore in December 1988, and draft revised RI sections submitted to the USEPA in March 1989.

The MSGS site is located in Cecil County, Maryland, near the town of Elkton. The site was operated as a sand and gravel quarry. Earth materials were removed from two areas--the Eastern Excavated Area (EEA) and the Western Excavated Area (WEA). Approximately 3 acres of the site in the EEA reportedly were used for the disposal of waste processing water, sludge, still bottoms, and about 90 drums of solid and semisolid waste between 1969 and 1974. Three pits in the EEA were used as surface impoundments, where approximately 700,000 gallons of waste were disposed. Two hundred thousand gallons of liquid waste were removed from the site in 1974. The drums and sludges that remained were buried onsite in the excavated pits in the EEA.

S.1 RESULTS OF PHASE I RI

The Phase I RI investigated wastes, surface soils, surface water, sediment, biota, and groundwater conditions at the site, with an emphasis on the EEA. The wastes were found to consist of a variety of chemicals. Surface soils in the EEA disposal ponds and in an adjacent seep were found to be contaminated with some of these compounds. One each of 23 soil and 13 waste samples collected at the site during Phase I were in the WEA and were reported to contain some of these same

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compounds; the compounds detected are also common analytical laboratory contaminants. The Phase I investigation of surface water found evidence of surface water contamination in the vicinity of the EEA, but found no evidence of offsite migration or surface water contamination. There was no evidence of contaminants in fish samples collected during Phase I. The Phase I RI focused on shallow groundwater in the EEA and found elevated concentrations of volatile organic compounds (VOC) in that area. The Phase I RI recommended a Phase II RI to investigate the possibility of waste disposal in the WEA; the possible migration of contaminants into the deep, unconsolidated groundwater and bedrock groundwater flow systems; and the extent of soil contamination onsite.

S.2 RESULTS OF PHASE I FS

The Phase I FS evaluated several remedial options for the site and concluded that remedial measures should be conducted in two phases. The remedial measures recommended were specific to the EEA only; they include excavation of buried materials (drums and/or trucks), offsite disposal of hazardous materials at an approved Resource Conservation and Recovery Act (RCRA) facility, and installation of shallow groundwater interceptors downgradient from the waste sources to collect the contaminated groundwater and leachate for treatment onsite before recirculating to the ponds and shallow groundwater or discharging to Mill Creek. A decision on the need for remedial measures for the contaminated soils, the lower unconsolidated sand and bedrock groundwater systems, final site closure requirements, and post-closure operation and maintenance (O&M) activities was deferred until completion of the Phase II RI/FS.

S.3 RESULTS OF PHASE II RI

S.3.1 RI Objectives

The objectives of the Phase II RI for MSGS were threefold:

- To investigate the possibility of a contamination source in the WEA. The Phase I RI had concluded that a source was in the EEA, but had not ruled out the possibility of a source in the WEA. There were no reports of waste disposal in the WEA.

- To evaluate the extent of soil contamination onsite, primarily in the WEA.

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- To investigate the presence of site-related contaminants in groundwater in the deep, unconsolidated and the bedrock groundwater systems. Specific objectives of the groundwater investigation included:
  - An evaluation of the extent of intercommunication among the various groundwater systems onsite.
  - An evaluation of the groundwater movement pattern in the deep, unconsolidated sediments and bedrock.
  - An evaluation of the concentrations of contaminants, if any, in groundwater in the deep, unconsolidated sediments and bedrock.
  - An evaluation of the effects of contamination, if any, on nearby residential, institutional, and community wells tapping the deep, unconsolidated sediments and bedrock.

S.3.2 Hazardous Substances Investigation

Surface soil sampling, shallow borings, and geophysical studies performed during the Phase II RI did not encounter contamination sources or evidence of general surface contamination in the WEA. The available evidence does not support the hypothesis of hazardous waste disposal in the WEA.

S.3.3 Soil Investigation

Field screening of over 400 soil samples and analysis of 137 soil samples by two laboratories (114 samples by one laboratory, 23 by the other) found virtually no contamination in the WEA, and the soils of that excavated area are considered to be uncontaminated. Soils analyses in the EEA concurred with the Phase I RI, which found significant soil contamination near the ponds used for waste disposal and surface seeps that receive discharge from the upper sand unit.

S.3.4 Hydrogeologic Investigation

The geology of the MSGS site consists of fluvial Potomac Group sediments that overlie fractured bedrock (gneiss). The sediments are sand, gravel, silt, and clay. Although the sediments exhibit marked lateral variations, there appear to be several laterally consistent lithologic units across much of the site. These units are:

- An upper sand unit (restricted to the EEA).

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- An upper silt and clay unit (also restricted to the EEA).
- A middle sand unit.
- A middle/lower silt and clay unit (which occurs as two units in the southwest portion of the site and appears to merge to northeast and southeast; the middle silt and clay is known to be absent in one location in the WEA).
- A lower sand unit, which is present in the northeast and southwest but is absent in the southeast.
- A zone of weathered bedrock (saprolite), present in all locations drilled into bedrock.
- Bedrock.

Information collected during the Phase II investigation indicates that there are four distinct but related groundwater flow systems at MSGS:

- A perched water table system in the upper sand unit of the EEA.
- A water table system in the middle sand unit along the valley of the western tributary to Mill Creek.
- A partially confined system in the deeper sediments (referred to as the lower sand unit).
- A bedrock system.

Groundwater flow in the perched water table system (upper sand unit) in the EEA flows toward seeps located west, southwest, and southeast of the EEA. Flow in the other water table system (middle sand unit) is generally south. The horizontal component of flow in the deeper units is toward the south-southwest. Vertical gradients between the deeper units are downward in the eastern portion of the site and upward in the southwestern portion.

Groundwater in the upper sand unit (EEA) contained higher concentrations of organic compounds than in groundwater elsewhere onsite. The upper sand unit in the EEA received the direct impact of waste disposal at MSGS, because wastes were reportedly disposed of in ponds in the EEA.

Groundwater in the middle sand unit in areas downgradient (south and southeast) of the EEA contained a suite of organic compounds similar to the upper

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sand unit but at generally much lesser concentrations. Elevated levels of organics were found in only one well. No elevated levels of metals or organic compounds were found in the middle sand unit in other areas of the site. Groundwater samples from the middle sand unit in the WEA also were analyzed for pesticides/polychlorinated biphenyls (PCB); none were found.

Water from the lower sand unit wells contained elevated but nonhazardous concentrations of certain metals. Some VOC's were present in samples from deep, unconsolidated sediments at low concentrations. Groundwater from bedrock wells onsite also contained low concentrations of metals and a few VOC's.

Potential groundwater migration pathways at MSGS include surface seeps from the EEA (which may reinfiltrate into the middle sand unit), leakage through confining units, vertical migration via zones where confining units are absent, and flow via potential conduits created by unconsolidated unit-penetrating boreholes. It is possible that contaminants migrated from the source area (upper sand unit in the EEA) through the seeps to the surface, reinfiltrated into the middle sand unit, and then were distributed deeper into the system via gaps in the middle silt and clay unit.

Analytical data for groundwater samples collected from offsite wells during the Phase II RI detected metals and a few VOC's; however, the volatiles were probable analytical laboratory artifacts. The metals in these water samples were not attributable to MSGS; however, in the case of lead, the metals may have been related to the plumbing system at the sampled residences. Data from the Phase I and Phase II RI's do not indicate that contaminants from the site have reached the offsite wells.

S.3.5 Surface Water and Sediment Investigation

Surface water and sediment sampling in the Phase II RI focused on isolated ponds in the WEA and on stream drainage that lies between the EEA and WEA. The surface water samples contained a variety of metals and were further characterized by low hardness and a pH of 3.7 to 5.6; however, the pH probably results from natural conditions. No significant concentrations of metals or organic analytes were found.

Sediment samples contained concentrations of metals that were within the range of natural variability. Low concentrations of volatile and semivolatile organic compounds were present in some of the samples. No pesticides/PCB's were detected in any surface water or sediment samples collected during the Phase II RI.

S.3.6 Public Health Evaluation

An Endangerment Assessment (EA) was conducted to assess potential human health effects that may result from exposure to site releases in the absence of remediation. Physical, chemical, demographic, and geographic factors were evaluated to assess the extent, if any, of potential harm to the public. Contaminants in the surface soil, sediments, surface water, and groundwater comprising the water table aquifer at the EEA were not addressed in the Phase II EA, because those media were addressed in the Phase I EA. Soils and sediments associated primarily with the EEA will be addressed in a Focused Feasibility Study.

The EA process involved the following components--contaminant identification, exposure evaluation, toxicity evaluation, and risk characterization. Exposure pathways were evaluated for two land use scenarios--current use and future use. Exposure doses and risks were calculated under conservative most-probable and worst-case conditions.

Because the site is open and residential areas are adjacent to the site, public access is possible. Therefore, a potentially complete pathway under the current-use scenario was defined as dermal and incidental ingestion by exposure to the sediment in the WEA. A potential future-use scenario for the site includes possible residential development up to the southern boundary. This scenario reflects public access to sediment and could result in groundwater supply wells that withdraw water from the middle sand unit, lower sand unit, and/or bedrock. Potential future exposure routes related to exposure to sediment are the same as those for the current use--dermal and incidental ingestion. Potential future exposure routes related to exposure to groundwater include ingestion, dermal absorption during bathing, and inhalation of vapors during water usage (e.g., bathing).

The Phase II EA found no potential human health risks in excess of the upper limit of USEPA's carcinogenic target range (10^{-4} to 10^{-7}) for any route of exposure, except potential future use of groundwater from the middle sand unit. The chemicals causing the potential future-use risks estimated for the middle sand unit were only detected in one well (DMW-07; EEA), with the exception of vinyl chloride and chloroform. Vinyl chloride also was detected in a 1987 sample from well D&M-03 (WEA) at an estimated (below the contract required detection limit) trace concentration (6 parts per billion--ppb). A more recent (1988) sample from well D&M-03 did not detect vinyl chloride, which suggests that the area of the middle sand unit exhibiting an elevated estimated future-use risk is limited to the vicinity of the EEA. Chloroform also was detected in a 1985 sample from well SMW-10 (WEA) at a concentration of 20.1 ppb, though it was not detected in this well in 1987 or 1988.

Estimated future-use risks for the lower sand and bedrock units are within the USEPA's carcinogenic target risk range of 10^{-4} to 10^{-7}. The chemical (tetrachloroethene) causing the potential future-use risks estimated for the bedrock unit has not been observed at concentrations in excess of the proposed maximum contaminant level (MCL) for this chemical (5 ppb) in any of the groundwater samples from this unit.

Two of the chemicals (benzene and chloroform) contributing to the risks associated with the lower sand unit also were not detected at concentrations in excess of their MCL's. There is no MCL for the only other chemical (1,4-dioxane) that contributes to the risks associated with the lower sand unit.

The hazard index (HI) for estimated noncarcinogenic hazards does not exceed 1.0 for any exposure scenario or media except the worst-case, future-use groundwater exposure scenario for the middle sand unit. The chemicals causing this single exceedance of the 1.0 HI level were detected in well DMW-07 (EEA) only.

S.4 RESULTS OF PHASE II FS

S.4.1 FS Objectives

Based on the results of the Phase II EA, this FS will address the issue of remediation of groundwater in the middle sand unit, and monitoring of groundwater in the lower sand and bedrock units.

S.4.2 Remedial Technologies and Alternatives Considered

Technologies that are potentially applicable to groundwater treatment/management at the MSGS site were preliminarily screened on the basis of implementability and technical feasibility. At this point, factors such as public health concerns and costs were also considered, but to a lesser extent. Technologies were grouped into three general categories as follows:

- Groundwater collection/control--Technologies for removing groundwater, preventing recharge, or preventing migration.
- Groundwater treatment--Technologies for removing contaminants from groundwater, either at a separate location or in situ.
- Management technologies--Technologies for controlling access to contaminated sources and/or for provision of alternative water supplies.

A total of 19 technologies were screened--five groundwater collection/control, seven groundwater treatment, and seven management--in addition to monitoring onsite and offsite wells.

Applicable remedial technologies were assembled into six remedial alternatives that addressed groundwater within the middle sand unit. The six alternatives addressed and their ability to meet the criteria for evaluation are shown in Table S-1.

S.4.3 Results of Detailed Analysis and Recommended Alternatives

The detailed analysis of the remedial action alternatives is summarized in Table S-1. This overview allows the six alternatives to be compared with regard to technical feasibility and implementability; protection of public health and the environment; long- and short-term effectiveness, permanence, and overall protection; applicable or relevant and appropriate requirement (ARAR) compliance; and cost. Based on the results of the detailed analysis, the use of onsite and offsite groundwater monitoring with onsite treatment (as necessary) utilizing the Phase I Record of Decision (ROD) system and offsite point-of-use treatment (as necessary) is the recommended Phase II remedial alternative (Alternative 6) for the MSGS site.

The recommended alternative includes monitoring of 11 onsite and four offsite wells. Onsite wells to be monitored include four new wells and seven existing wells. These wells are located upgradient and downgradient along the boundary of the waste management area and provide monitoring of the middle sand, lower sand, and bedrock units. The upper sand unit is excluded, because it will be closely monitored during implementation of the Phase I ROD.

Phase II monitoring is expected to be initiated in early 1990, based on a Phase II ROD in mid-1989 and a time allowance for design, design approvals, and construction of new monitoring wells. Quarterly samples will be taken from the middle and lower sand unit wells and analyzed for TCL volatiles. These wells will be sampled annually for TAL metals. Bedrock wells will be sampled annually and tested for VOC's and metals. The scope of monitoring, such as parameters, frequency, duration, etc., will be reviewed and evaluated periodically.

This program will continue until 2 years after startup of the Phase I treatment system (currently projected as mid-1992, or approximately 4 years of monitoring). At this time, VOC sampling of the middle and lower sand units will be reduced to semiannually, until a total of 5 years has elapsed and the monitoring program is reevaluated.

For costing purposes, it is assumed that the middle sand, lower sand, and bedrock units will be monitored annually for Target Compound List (TCL) VOC's and Target Analyte List (TAL) metals for an additional 25 years.

Offsite monitoring will be conducted on an annual basis, with review of the program every 5 years. A total offsite monitoring period of 30 years is assumed for costing purposes. Samples will be analyzed for TCL VOC's and TAL metals. Offsite monitoring encompasses four wells serving both residences and businesses. The locations of offsite wells to be monitored were selected to maximize the likelihood of detection of potential analytes from MSGS. Most of the locations are to the immediate south of MSGS, in the downgradient groundwater flow direction. The monitoring locations also were selected to provide complete coverage of the MSGS property to minimize the future possibility of groundwater analytes flowing between monitoring points. As with the onsite treatment program, the monitoring schedule and number of monitored wells may be expanded (as necessary) to provide information on plume migration. The scope of monitoring, such as parameters, frequency, duration, etc., will be reviewed and evaluated periodically.

A large-volume groundwater user is included in the monitoring plan to account for the possibility that groundwater analytes may preferentially be drawn toward this location. Available groundwater monitoring data do not indicate that this is occurring.

Onsite pumping and treating of groundwater from the middle sand unit will be considered only after the potential contaminant sources within upper sand unit groundwater, soils, and sediments at the EEA have been eliminated or controlled (i.e., remedies have been successfully implemented), and if the onsite groundwater monitoring shows an increase in analyte concentrations in the deeper water-bearing units, despite implementation of the Phase I ROD groundwater treatment system. Although onsite development is not anticipated during the period of possible onsite treatment, water use controls to prohibit the onsite use of groundwater should be considered during final system design. Offsite point-of-use treatment will be initiated on a well-by-well basis after indicator chemicals from an MSGS source have been confirmed in an offsite drinking water well(s).

In addition, institutional controls may be instituted in the future (if necessary) to prevent the use of groundwater onsite before remedial objectives have been achieved.

By reviewing the major screening factors that were used for each alternative, it is evident that the recommended remedial action provides for:

- Technical feasibility and implementability.
- Overall protection of public health and the environment.
- Compliance with potential ARAR's.
- Long-term effectiveness and permanence, as well as short-term effectiveness.
- Overall reduction of toxicity, mobility, and volume of contamination.
- Acceptable levels of capital and O&M costs.

This alternative was recommended over other alternatives due to the additional level of reduction in toxicity, mobility, and volume provided by onsite treatment and the protection of public health and the environment provided by offsite point-of-use treatment.

Table S-1
Summary Table of Remedial Alternatives
Narrative Matrix

Alternative	Implementability	Impacts on Effectiveness, Public Health and the Environment	Compliance with ARARs	Cost (thousands of dollars) Capital	O&M	NPW(a)
1-No Action	Not Applicable	No remediation. Risks presented in EA will be lowered only by Phase I ROD actions and/or natural mechanisms.	Clean Water Act and/or Safe Drinking Water Act MCL restrictions are violated onsite.	0	0	0
2-Onsite Groundwater Monitoring	Reliable, low O&M requirements. Low/no health risks during installation. No reduction of toxicity, mobility or volume of compounds as a direct result of implementation. Useful life equals 30 years. Short term increases in noise and dust.	Minimal/no short-term risk to public health/environment. Risk from future groundwater use still exists. Remedial objectives not achieved via remediation.	Clean Water Act and/or Safe Drinking Water Act MCL restrictions are violated onsite. Clean Air Act and OSHA Regulations would be met via workplan specifications.	80	44	464
3-Onsite and Offsite Groundwater Monitoring	Reliable, low O&M requirements. Low/no health risks during installation. No reduction of toxicity, mobility or volume of compounds as a direct result of implementation. Useful life equals 30 years. Short term increases in noise and dust.	Minimal/no short-term risk to public health/environment. Risk from future groundwater use still exists. Remedial objectives not achieved via remediation.	Clean Water Act and/or Safe Drinking Water Act MCL restrictions are violated onsite. Clean Air Act and OSHA Regulations would be met via workplan specifications.	80	51	550
4-Onsite and Offsite Groundwater Monitoring with Deferred Offsite Point-of-Use Treatment	Treatability studies required. Useful life of 30 years. Operationally simple and reliable. Rapid installation, immediately operable.	Minimal/no short-term risks during installation. Proper O&M necessary to maintain effectiveness. Used resin and/or carbon may be hazardous.	Would meet MCL's at point-of-use. OSHA, Clean Air Act and DOT regulations would be met via work plan specifications.	80(d) 516(e)	51(d) 115(e)	550(d) 1,590(e)
5-Onsite Groundwater Monitoring with Deferred Onsite Groundwater Treatment (Phase I System)	Impacts of Phase I system evaluated in Phase I FS. Useful life of 30 years	Short-term, temporary increases in noise and dust levels. Minimal/no risks to public health/environment during installation or operation. Impacts of Phase I system evaluated in Phase I FS. Risk of undetected offsite groundwater degradation and subsequent use still exists.	Meets or exceed all potential ARARs onsite OSHA and DOT regulations addressed in work plan.	80(b) 1,116(c)	44(b) 496(c)	464(b) 3,213(c)
6-Onsite and Offsite Groundwater Monitoring with Deferred Offsite and Onsite Treatment	Impacts of Phase I system evaluated in Phase I FS. Useful life of 30 years	Short-term, temporary increases in noise and dust levels. Minimal/no risks to public health/environment during installation or operation. Impacts of Phase I system evaluated in Phase I FS.	Meets or exceed all potential ARARs onsite OSHA and DOT regulations addressed in work plan.	80(b)(d) 516(b)(e) 1,116(c)(d) 1,552(c)(e)	51(b)(d) 115(b)(e) 501(c)(d) 671(c)(e)	550(b)(d) 1,590(b)(e) [illegible](c)(d) 4,337(c)(e)

Key: (a) Net present worth; evaluated at a 10% discount rate for 30 years.
(b) If onsite treatment is not necessary.
(c) If onsite treatment is necessary.
(d) If offsite treatment is not necessary.
(e) If offsite treatment is necessary.

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1.0 INTRODUCTION

1.1 OVERVIEW OF THE FEASIBILITY STUDY REPORT

This approach to analyzing remedial alternatives conforms to the requirements under Subpart F of the National Contingency Plan (NCP), as described in 40 CFR Part 300 (Section 300.68). The approach to screening and evaluating remedial options contains the elements or procedures described in U.S. Environmental Protection Agency (USEPA) documents that provide guidance for complying with the Subpart F requirements (USEPA, 1986; USEPA, 1985a; USEPA, 1984; USEPA, 1988). The Office of Solid Waste and Emergency Response Directive Numbers 9355.0-19 and 9355.3-01 address requirements promulgated by the Superfund Amendments and Reauthorization Act (SARA) of 1986 and subsequent revisions.

Subpart F of the NCP provides a general framework for conducting a phased evaluation of possible remedial options and for identifying remedial alternatives that are "consistent with permanent remedy to prevent or mitigate the migration of a release of hazardous substances into the environment."

Section 2.0 presents a preliminary screening of remedial action technologies based on their technical applicability to treating groundwater under the site conditions at the Maryland Sand, Gravel and Stone (MSGS) site. These technologies address the general response actions outlined below:

Groundwater

- No action
- Containment
  - Capping
  - Subsurface barriers
  - Access limitations
- Collection/Control
  - Pumping
  - Subsurface drains
  - Infiltration trenches/basins

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- Treatment
  - Biological treatment
  - Chemical treatment
  - Physical treatment
- Management technologies.

These general response actions are recommended by USEPA and are intended to broadly define the nature of the various groundwater treatment technologies that will be considered for use at the MSGS site. In general, they address the issues of source control measures (measures designed to prevent or minimize the migration of hazardous substances from the source) and management of migration measures (measures designed to mitigate the impact of contamination that has migrated into the environment) (USEPA, 1985b).

Technologies that pass the initial screening (Section 2.0) are then combined to form remedial alternatives (Section 3.0), which are screened and then evaluated in detail (Section 4.0). The detailed analyses encompass engineering, institutional, public health, environmental, and cost analyses. The engineering analysis evaluates constructability and reliability to ensure the implementability of alternatives. The institutional analysis examines alternatives in terms of the Federal, state, or local requirements, advisories, or guidance that must be considered to protect public health and welfare and the environment.

The public health exposure evaluation includes a base line site evaluation, exposure assessment, standards analysis, a permanence and short- and long-term effectiveness evaluation, and the overall protection of each alternative. An Endangerment Assessment (EA) has already been conducted as part of the Phase II Remedial Investigation (RI) (see Section 1.3 for the scope of the EA). The environmental analysis includes an assessment of adverse impacts if no action is taken and the short- and long-term effects of the alternatives, as well as an evaluation of the reduction in toxicity, mobility, and volume as a result of implementation of the alternative. The cost analysis examines capital and operation costs and involves (where applicable) present worth and sensitivity analyses.

Once the detailed analyses are complete, the information is organized into a narrative matrix to compare findings of the evaluations for each alternative. The

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objective of this summary (Section 5.0) is to ensure that important information is presented in a concise format so that the alternative that provides the best balance between health and environmental protection, and engineering reliability and cost, can be clearly determined (USEPA, 1985a).

1.2 SITE BACKGROUND

1.2.1 Site History

The MSGS site is located in Elkton (Cecil County), Maryland, at 75°53'54" longitude and 30°36'53" latitude on the U.S. Geological Survey (USGS) North East, Maryland, 7.5-minute quadrangle map. Consisting of approximately 200 acres, the site is located north of U.S. Route 40 and along a tributary of Mill Creek about 3 miles west of the town of Elkton (Figure 1-1). It is situated within the western portion of a triangle formed by Marley Road to the northwest, Nottingham Road to the northeast, and U.S. Route 40 (Pulaski Highway) to the south (Figure 1-2).

The site was previously operated as a sand and gravel quarry under the name Maryland Sand, Gravel and Stone Company. In December 1979, Lester Summers--President of the Maryland Sand, Gravel and Stone Company--informed the Maryland Department of Natural Resources that the site was for sale (Maryland Department of Natural Resources, 1980), though no sale has since transpired.

Approximately 3 acres of the site were used for the disposal of waste processing water, sludge, still bottoms, and about 90 drums of solid and semisolid waste between 1969 and 1974 (Summers, 1975). On July 16, 1974, 1,300 gallons of flammable products stored in drums were reportedly received and dumped; on August 5, 1974, 5,000 gallons of nonflammable materials were received at the site (Summers, 1974). Pits, excavated onsite, were used as surface impoundments, where approximately 700,000 gallons of waste were dumped (Stone and McGovern, 1982).

On April 27, 1974 (1 p.m.), a pool of chemical waste ignited and burned at high intensity before it was extinguished. The cause of the fire was not determined (Hill, 1974).

Two hundred thousand gallons of liquid waste were removed in 1974. The drums and sludges that remained were buried onsite in excavated pits (NUS Corporation, 1983).

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Several seeps can be observed at the site. Some seeps are located south of pond P01, one seep is in the wooded area east of pond P02, and other seeps are located downgradient on a hillside west of pond P03 in the Sedge Meadow Area. The seeps and surface water runoff from the western and southern sections of the site drain into the western tributary of Mill Creek. The Sedge Meadow Area is a hillside located downgradient between pond P03 and the western tributary of Mill Creek.

A portion of the site located west of the Sedge Meadow Area has undergone excavation; however, the specific nature of the activities that occurred in this area is unknown.

1.2.2 Summary of Previous Investigations and Remedial Investigation Findings

A history of site use, permit and regulatory actions, and remedial actions is presented in Appendix A of the Phase I RI Report.

The Phase I RI/Feasibility Study (FS) was performed at the MSGS site by AEPCO, Inc., under subcontract to NUS Corporation, a regional contractor for the USEPA. The objectives of that RI/FS were to:

- Characterize the types and extent of contamination.
- Evaluate alternative remedial actions for the MSGS site.
- Recommend a cost-effective remedial action.

The findings of the Phase I RI/FS are presented in the report dated September 4, 1985.

Several unresolved issues were identified as a result of the waste and environmental sampling and analysis program that was conducted during the Phase I RI/FS, namely:

- The existence or absence of contamination in the two deeper aquifers--the deep, unconsolidated and bedrock aquifers.
- The existence or absence of a contamination source in the Western Excavated Area (WEA) of the site.
- The determination of the extent of soil contamination onsite.

Further study and review of these issues by AEPCO, Inc. (NUS Corporation subcontractor), USEPA, State of Maryland Department of Health and Mental

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Hygiene (now Maryland Department of the Environment), and NUS Corporation (USEPA contractor) revealed that the conduct of a supplementary RI/FS (Phase II) would be necessary. The Phase II RI/FS was conducted by Dames & Moore to address these unresolved issues.

Surface soil sampling, shallow borings, and geophysical studies performed during the Phase II RI showed no evidence of contamination sources or hazardous waste disposal in the WEA of the site. In addition, soil samples indicated no significant soil contamination.

Groundwater, surface water, and sediment samples in the WEA indicated no significant contamination. An EA for the Phase II RI concluded that there are no unacceptable risks to human health associated with the soil or sediment in the WEA. Potential groundwater carcinogenic health risks in excess of USEPA's carcinogenic risk range of 10^{-4} to 10^{-7} at the MSGS site were determined by the EA to be due to the occurrence of contamination in the middle sand unit at the EEA. The potential future use of groundwater from the middle sand unit was determined to pose a worst-case potential risk of 2.51×10^{-2}.

1.2.3 Environmental Setting

1.2.3.1 Demography. Cecil County has a population of 60,428, as recorded in January 1984 (Maryland Department of Economic and Community Development, 1984), with a population density of about 172 persons per square mile. This represents approximately 1.5 percent of the total population of Maryland, as recorded in 1980 by the U.S. Bureau of the Census and the Maryland Department of State Planning. Within a 1-mile radius of the site, there are approximately 150 units housing approximately 570 residents (Ecology and Environment, Inc., 1982).

The population projection for the years 1985, 1990, and 2000, as estimated by the U.S. Bureau of the Census and the Maryland Department of State Planning, shows a steady growth pattern of 63,500, 66,600, and 70,800, respectively (Maryland Department of Economic and Community Development, 1984).

Elkton, a town of 6,468 residents according to the 1980 Census report (Maryland Department of Economic and Community Development, 1984), is located approximately 3 miles east of the site. The town of North East, located approximately 1.8 miles west-southwest of the site, has a population of 1,469.

1.2.3.2 Land Use. Cecil County, located in the northeastern corner of Maryland, is one of the smallest counties in the state, covering only 352 square miles. The county is bounded by Pennsylvania to the north, Delaware to the east, Kent County along the Sassafras River to the south, and the Chesapeake Bay and the Susquehanna River to the west. U.S. Route 213 runs north and south in the county, intersecting Pulaski Highway (U.S. Route 40). U.S. Route 40, as well as Interstate I-95, runs east and west.

Cecil County is becoming less of a rural area partially because of the influence of the growing northern Delaware metropolitan area. Slightly less than 3 percent of the total land--or 6,191 acres--is used for cultivated crops, and about 2 percent (4,526 acres) of Cecil County land is better suited for intensive use as pasture. These pasturelands occupy long, narrow strips along the major streams of the county and are not suited for cultivation because of periodic flooding and poor internal drainage. About 7 percent (15,708 acres) of the land is suited for moderate use as pastureland (U.S. Department of Agriculture, 1973).

Industrial development has progressed in recent years, as exemplified by the production of major chemicals, rubber products, rocket motors, textiles, and industrial wire and cable. Small industries include home construction, luggage manufacture, and medical products.

Land use onsite and within an approximate 1.5-mile radius of the site can be categorized as follows, as of June 1983 (Mata, 1983):

- Urban or builtup land (residential, commercial, industrial, transportation/commercial, utilities, and mixed urban and builtup land).
- Agricultural (cropland and pasture and farmsteads and farm-related enterprises).
- Range (shrub-brush and mixed range).
- Forest (deciduous, evergreen, mixed, and clear-cut).
- Water (natural lakes and ponds and manmade reservoirs and impoundments).
- Barren land (extractional and transitional).

Land use at the project site and within the vicinity of adjacent Marley Road, Nottingham Road, and U.S. Route 40 is categorized below:

Land Use	Area (%)
Mixed forest	55
Clear-cut forest	1-5
Residential	11
Commercial	2
Cropland and pasture	17
Barren lands	11
Mixed urban/builtup land	2
Manmade reservoirs	0-5

Residents near the site rely almost exclusively on groundwater for their water supply and on septic tanks/absorption fields for the disposal of their domestic sewage. Municipal water from Elkton is gradually being extended westward toward the site.

1.2.3.3 Natural Resources in the Vicinity of the MSGS Site. The site covers approximately 200 acres, with two major excavated areas--one in the eastern portion and one in the western portion of the site. The site contains three ponds (P01, P02, and P03), the Sedge Meadow Area, a swamp, an Old Sedimentation Pond, and an upper reach of the western tributary of Mill Creek. The western tributary of Mill Creek--originating at the Sedge Meadow Area--dissects the site, initially flows southward, then turns east south of the Old Sedimentation Pond and joins the eastern tributary of Mill Creek offsite directly east of Ephrata Lane. A number of seeps, springs, and intermittent streams also are present at the site. All of the seeps and streams eventually feed to the western tributary of Mill Creek. Several low-lying areas are mostly dry but occasionally fill with water after precipitation.

Most of the site is visually buffered by wooded areas from adjacent properties and roadways, including U.S. Route 40 (Pulaski Highway) to the south, Marley Road to the northwest, and Nottingham Road to the northeast. Nevertheless, traffic noise from U.S. Route 40 is noticeable near the Lower Haul Road, approximately 1,200 feet north of U.S. Route 40.

Other unique onsite features are listed below:

- The site--once a source of sand, gravel, and stone--has been inactive for some time. As a result of the extraction activities for these materials, the site has been drastically modified and is now characterized by undulating terrain. The highest point is 188.5 feet above mean sea level (msl), and the lowest spot at the southeastern corner of the site is just below 94 feet above msl.

- The area surrounding the site is mostly residential. Groundwater is the primary source of drinking water for these residents.
- The site is used extensively by all terrain vehicles, despite efforts to restrict access to the site.
- Seeps are visible directly downgradient of pond P01, in the wooded area east of pond P02, and in the Sedge Meadow Area immediately downstream and west of pond P03.
- A telephone right-of-way runs along the southern edge of the site.

1.2.3.4 Geology and Hydrogeology. The geology of the MSGS site consists of fluvial Potomac Group sediments that overlie fractured bedrock (gneiss). The sediments are sand, gravel, silt, and clay. Although the sediments exhibit marked lateral variations, there appear to be several laterally consistent lithologic units across much of the site. These units are:

- An upper sand unit (restricted to the Eastern Excavated Area (EEA)).
- An upper silt and clay unit (also restricted to the EEA).
- A middle sand unit.
- A middle/lower silt and clay unit (which occurs as two units in the northeast and southwest portions of the site and appears to merge to the southeast; the middle silt and clay unit is known to be absent in one location in the WEA).
- A lower sand unit, which is present in the northeast and southwest but is absent in the southeast.
- A zone of weathered bedrock (saprolite), present in all locations drilled into bedrock.
- Bedrock.

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Information collected in the Phase II investigation indicates that there are four distinct but related groundwater flow systems at MSGS:

- A perched water table system in the upper sand unit of the EEA.
- A semiconfined system in the middle sand unit along the valley of the western tributary to Mill Creek.
- A partially confined system in the deeper sediments.
- A bedrock system.

Groundwater flow in the perched water table system in the EEA flows toward seeps located west, southwest, and southeast of the EEA. Flow in the semiconfined portion of the middle sand unit is generally south. The horizontal component of flow in the deeper units is toward the south-southwest. Vertical gradients between the deeper units are downward in the eastern portion of the site and upward in the southwestern portion.

1.2.3.5 Climatology. Cecil County is characterized by a humid, continental climate with well-defined seasons. The Chesapeake Bay and its tributaries and the Atlantic Ocean affect the climate, particularly by moderating extreme temperatures. Table 1-1 shows climatic data for the county, based on Elkton records (National Weather Service, 1941-1960).

The warmest part of the year is during the last half of July, when the maximum afternoon temperatures average near 90°F. Temperatures of 90°F or higher occur about 34 days per year. The coldest period is during late January and the beginning of February, when early morning temperatures average 22°F. The average number of days with temperatures less than 32°F is 111.

Freeze data for the spring and early fall are also shown in Table 1-1. The growing season between the last 32°F temperature in spring and the first one in fall averages 181 days at Elkton.

The annual precipitation at Elkton has ranged from a low of 26.96 inches in 1930 to a high of 58.01 inches in 1945. The monthly distribution of precipitation, however, is fairly uniform throughout the year, with slightly higher precipitation levels during August.

The maximum total precipitation for any one month was measured at 15 to 18 inches in August 1955, when two hurricanes crossed Maryland. The average annual snowfall is 21 inches, but there is considerable variation from year to year, ranging from a trace in 1949 to 58.8 inches in 1958. The chances of drought occurring are very low. Generally, the rainfall and stored soil moisture are adequate for good crop growth, but in some years the unequal distribution of summer showers and occasional dry periods at critical stages in crop development made irrigation necessary for maximum crop growth.

Thunderstorms occur on the average of about 30 days per year, with hail occurring about 1 or 2 days per year. Tornadoes are rare and have caused very little damage in the past. Tropical storms affect the county about once each year, usually during August through October. Most of these have caused only minor damage.

Prevailing winds are from west-northwest to northwest, especially in winter months. From May through September, the area is dominated by southerly winds. The average annual wind speed is about 9 or 10 mph. Wind speeds reach 50 to 60 mph and even higher during severe thunderstorms, hurricanes, or winter storms.

1.3 NATURE AND EXTENT OF PROBLEM

The Phase II RI included an EA, which evaluated potential health risks associated with soil, groundwater, and sediments at the WEA and groundwater within semiconfined water-bearing units (middle sand, lower sand, and bedrock units) at the EEA. The available data and the results of the EA analysis--under specific exposure assumptions that are detailed in the Phase II RI--indicate that the principal unacceptable human health hazards are posed by groundwater within the middle sand unit in the EEA. If benzene and chloroform are excluded from the risk assessment for the lower sand and bedrock units (because the detected concentrations did not exceed MCL's), then risks associated with the bedrock unit are zero, and risks associated with the lower sand unit are slightly in excess of 1×10^{-6} (due only to the occurrence of 1,4-dioxane). No unacceptable human health hazards are posed by surface water, sediments, or soil throughout the WEA at MSGS.

The current-use pathway at the site is complete for exposure to soil and sediment. Total current-use carcinogenic risks for both the most-probable and

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worst cases for both media are well within the acceptable carcinogenic target range, as defined by USEPA. The total noncarcinogenic hazard indices (HI) are well below the action level of 1.0 for both the most-probable and worst cases for both media.

The future-use pathway at MSGS is complete for exposure to sediment and groundwater at the southern MSGS boundary. Exposure concentrations for indicator chemicals for the worst-case scenario were estimated from analyte concentrations in monitoring wells at the southern MSGS boundary. Total future-use carcinogenic risks for sediment are within the acceptable range for both the most-probable and worst cases. The HI's for future noncarcinogenic exposures are all below 1.0.

1.4 GROUNDWATER REMEDIAL ACTION OBJECTIVES

The base line Phase II EA for MSGS described the contaminants of concern for MSGS based on an evaluation of the occurrence of contamination at MSGS and associated potential exposure routes and receptors. This EA concluded that potentially unacceptable future human health risks/hazards may be posed by some of the contaminants of concern because of their occurrence in groundwater, principally within the middle sand unit.

The carcinogenic contaminants of concern causing the elevated potential carcinogenic risk levels within the middle sand unit were chloroform; 1,1-dichloroethene; trichloroethene; tetrachloroethene; and vinyl chloride. The remediation goals for these compounds are MCL's or proposed MCL's.

The contaminants of concern with noncarcinogenic effects causing the HI to exceed 1.0 due to consumption of groundwater from the middle sand unit are primarily chloroform; 1,1-dichloroethene; and 1,1,1-trichloroethane. Lead is excluded from this list, though the HI specified for lead for the middle sand unit under the worst-case exposure scenario is similarly elevated compared to the HI's for the preceding three chemicals (see Table 7-33, Phase II Remedial Investigation, Final RI Report; Dames & Moore, 1989b). Lead is excluded, because the elevated HI reported for lead in Table 7-33 (Phase II RI) is an artifact of the protocol for performing a simple statistical summary (i.e., estimating maximum, minimum, and mean concentrations). This protocol requires that one-half of the detection limit be assumed for samples in which inorganic analytes were not detected. For some of the 1985 groundwater samples from monitoring wells within the middle sand unit, lead was not detected; however, the detection limits were elevated (50 ug/l). The assumption of one-half of the detection limit (25 ug/l) causes an artificial, elevated HI for lead for the middle sand unit. The lead HI's for the lower sand and bedrock units are genuinely elevated (but still well below 1.0) due to positive detections of lead. However, the cumulative HI's for the lower sand and bedrock units are less than 1.0; therefore, there are no remedial requirements to reduce the cumulative HI for either the lower sand or bedrock unit.

Regarding chloroform; 1,1-dichloroethene; and 1,1,1-trichloroethane, the remediation goals for the compounds are MCL's (if available) or the concentrations that allow the cumulative HI for all noncarcinogenic contaminants of concern to be less than 1.0, whichever is less. Excluding chloroform; 1,1-dichloroethene; 1,1,1-trichloroethane; and lead, the cumulative worst-case future-use HI for groundwater consumption from the middle sand unit is 0.1. Therefore, the remediation goals for chloroform; 1,1-dichloroethene; and 1,1,1-trichloroethane must correspond to an HI of 0.3 for each chemical so that the sum of the cumulative HI for these three contaminants of concern (0.9) and the cumulative HI for the remaining (excluding lead) noncarcinogenic contaminants of concern (0.1) does ot exceed 1.0.

Table 1-3 presents the concentrations of chloroform, 1,1-dichloroethene, and 1,1,1-trichloroethane corresponding to individual HI's of 0.3, giving a total HI of 1.0 for the middle sand unit. It is assumed that the exposure scenario is consumption fo 2 liters per day by an adult weighing 70 kilograms.

HI's for the lower sand and bedrock units are already less than 1.0, as indicated by the base line EA. Therefore, treatment of groundwater from these units for the purpose of reducing noncarcinogenic health hazards is not necessary, and these units are not addressed herein.

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TABLE 1-1

Temperature and Precipitation at
Elkton, Cecil County, Maryland

Month	Temperature (°F)				Precipitation (inches)[b]		
	Average Daily Maximum	Average Daily Minimum	Maximum[a] (equal to or higher than)	Minimum[a] (equal to or lower than)	Average Total	Less Than	More Than
January	42.4	25.1	60	10	3.46	1.9	6.3
February	44.2	24.9	60	13	2.99	1.9	4.5
March	52.8	31.4	72	19	4.19	2.1	6.3
April	64.9	40.7	82	29	3.60	1.4	6.9
May	75.7	50.8	88	39	4.25	1.4	7.7
June	84.0	59.6	94	48	3.96	1.7	7.4
July	87.9	64.5	96	55	4.35	1.0	8.0
August	86.1	62.9	95	51	5.02	1.4	9.4
September	79.7	55.9	91	42	3.56	1.0	7.1
October	68.6	44.4	84	32	3.23	1.6	6.0
November	56.1	34.6	69	24	2.55	0.8	6.4
December	44.2	26.3	60	12	3.19	1.3	5.8
Yearly	65.6	43.4	99	2	45.35	37.0	52.6

Source: National Weather Service, U.S. Department of Commerce, 1941-1960.

[a]Data are based on estimates for 1 year in every decade.

[b]Predicted precipitation for 1 year in every decade.

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TABLE 1-2

Remediation Goals for Middle Sand Unit Contaminants of Concern With Potential Carcinogenic Effects

Contaminant of Concern	MCL and Groundwater Remediation Goal (ug/l)
Chloroform	100[a]
1,1-Dichloroethene	7
Trichloroethene	5
Tetrachloroethene	5[b]
Vinyl Chloride	2

[a]The MCL is for total trihalomethanes, of which chloroform is a component.

[b]Proposed MCL.

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TABLE 1-3

Remediation Goals for Middle Sand Unit Contaminants of Concern With Noncarcinogenic Effects

Contaminant of Concern[a]	Concentration Corresponding to an HI of 0.3 (ug/l)	MCL (ug/l)	Groundwater Remediation Goal (ug/l)
Chloroform	105	100	100
1,1-Dichloroethene	945	7	7
1,1,1-Trichloroethane	945	200	200

[a]These are the contaminants of concern identified in the base line EA for MSGS that are predominantly responsible for causing the HI for the oral exposure route to exceed 1.0 for the worst-case future use of middle sand unit groundwater (Dames & Moore, 1989b, Table 7-33).

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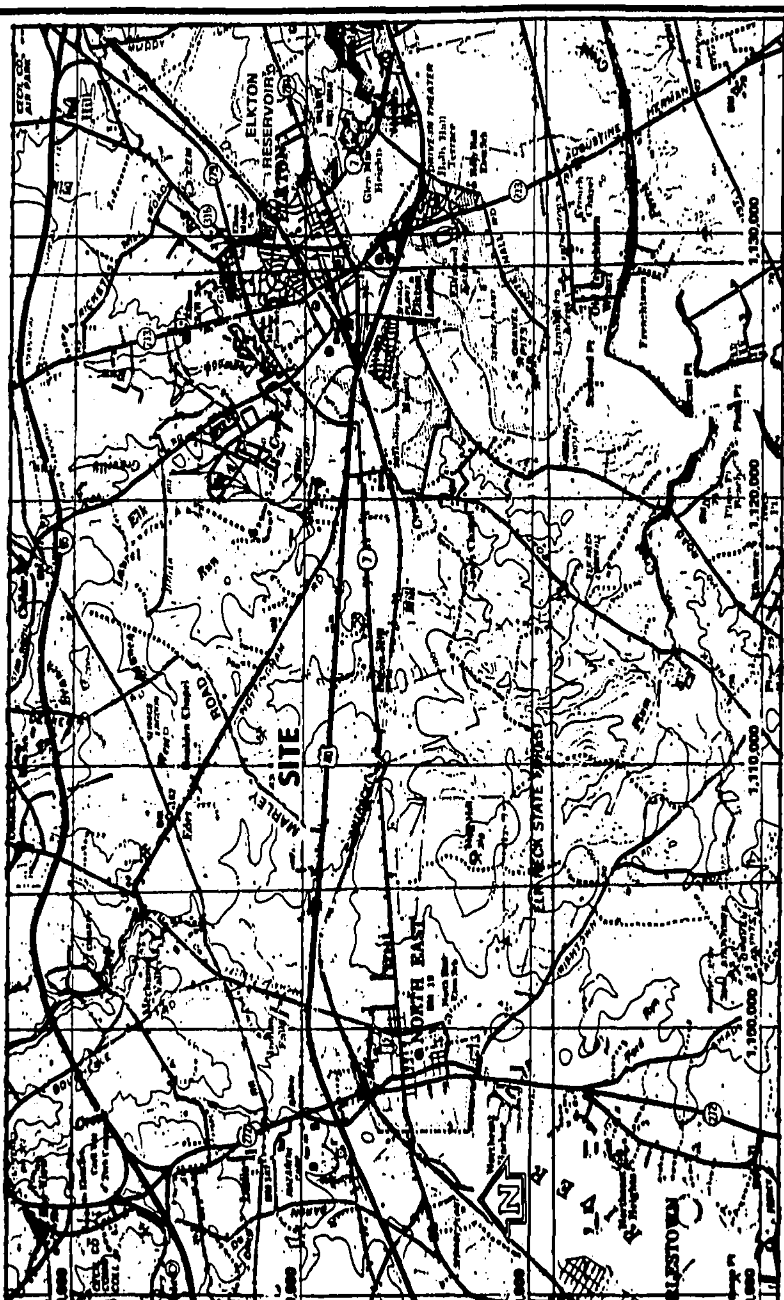

Source: Topographic Map of Cecil County, Maryland Geological Survey, 1977

0 2000 Feet

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FIGURE 1-1
VICINITY MAP

Dames & Moore

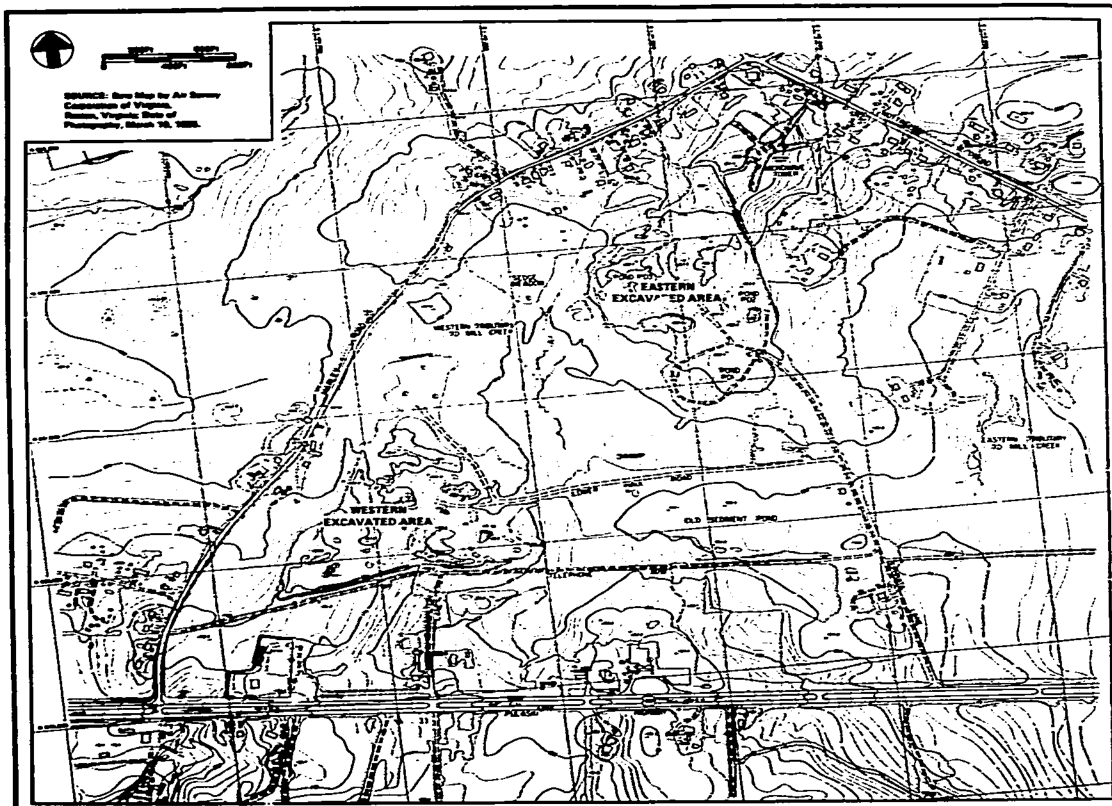

FIGURE 1-2
SITE MAP

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2.0 PRELIMINARY SCREENING OF REMEDIAL ACTION TECHNOLOGIES

2.1 METHODOLOGY

This section presents a preliminary screening of technologies that are potentially applicable to groundwater treatment/management at the MSGS site. This screening is conducted on the basis of technical feasibility only; other factors such as public health concerns and costs are discussed but will not (at this point) be the primary basis for eliminating technologies from further consideration. The technologies reviewed fulfill the general response actions recommended by the USEPA. The individual technologies were chosen based on information on the nature and extent of the low levels of contamination found, as well as the environmental setting, which were presented earlier in this report and in the Phase II RI Report. Table 2-1 presents a summary of the preliminary screening.

2.2 GROUNDWATER COLLECTION/CONTROL

Remedial technologies for the control of groundwater contamination can be placed in one of four categories: (1) groundwater pumping, involving the extraction of water from or injection of water into wells to capture a plume or alter the direction of groundwater flow; (2) surface water diversion to control leachate formation; (3) subsurface drains, consisting of gravity collection systems designed to intercept groundwater; and (4) containment barriers, consisting of a vertical wall of low-permeability materials constructed underground to divert groundwater flow or minimize leachate generation and plume movement (USEPA, 1985b).

2.2.1 Groundwater Pumping/Control

Extraction of groundwater from the middle sand unit using groundwater extraction wells is a feasible technology for groundwater collection/control, though difficulties may be encountered due to low hydraulic conductivities and the heterogeneous characteristics of the unit. Groundwater pumping techniques actively manipulate groundwater to contain, divert, or remove a plume or to adjust groundwater levels (prevent formation of a plume). Types of wells used in management of contaminated groundwater include suction wells and injector wells. Selection of the appropriate well type depends on the depth of contamination and the hydrologic and geologic characteristics of the aquifer.

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Wellpoint systems are best suited for shallow aquifers where extraction is not needed below 22 feet. Beyond this depth, suction lifting (the standard pumping technique for wellpoints) is ineffective. Suction wells operate in the same way and are also depth limited. The advantage of suction wells over wellpoints is their higher capacities. In addition, submersible pumps may be used. For extraction depths greater than 20 feet, deep wells and injector wells are used. Deep well systems are better suited to homogeneous aquifers with high hydraulic conductivities and where large volumes of water may be pumped.

Where plume containment or removal is the objective, either extraction wells or a combination of extraction and injection wells can be used. Extraction wells alone are best suited to situations where contaminants are miscible and move readily with water, where the hydraulic gradient is steep and hydraulic conductivity is high, and where quick removal is not necessary. Extraction wells are frequently used in combination with slurry walls to prevent groundwater from overtopping the wall and to minimize contact of the leachate with the wall to prevent wall degradation.

A combination of extraction and injection wells is used in containment or removal where the hydraulic gradient is relatively flat and hydraulic conductivities are only moderate. The injection well directs contaminants to the extraction wells. This method has been used successfully for plumes that are immiscible with water. One problem with such an arrangement of wells is that dead spots (i.e., areas where water movement is very low or nonexistent) can occur when these configurations are used. The size of the dead spot is directly related to the amount of overlap between adjacent radii of influence; the greater the overlaps, the smaller the dead spots. Injection wells can also suffer from operational problems, including air locks and the need for frequent maintenance and well rehabilitation.

2.2.2 Surface Water Diversion and Control

Surface water diversion is used to control the flow patterns of surface water to prevent the leaching of wastes into groundwater. The results of the Phase II RI and the Bioassessment Report (CDR, 1988) indicated that surface contamination sources are not evident at the WEA. The few analytes detected at the surface along roadways at the WEA were likely derived from the original source area at the EEA. Further, the results of the Phase II EA do not indicate unacceptable public or

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environmental hazards associated with the analytes detected at the surface at the WEA. The Phase I Record of Decision (ROD) for the EEA calls for removal of contaminant sources (drums and/or cement mixer barrels), which will affect reduction of leachate generation. To supplement excavation, the ROD includes a system of shallow groundwater interceptors downgradient from waste sources.

However, surface water controls would be useful in conjunction with an extraction/reinjection system, especially if treated groundwater is to be discharged to the surface (in ponds, Mill Creek, an infiltration gallery, or by land application). These controls could serve to direct surface flow toward a recharge area (such as a pond, seep, or infiltration trench) to provide flushing for the groundwater units being pumped and provide a hydraulic barrier to offsite migration of groundwater. The surface water control most applicable to the MSGS site is an infiltration trench.

2.2.2.1 Infiltration Trenches. Infiltration trenches or basins (also known as infiltration galleries or seepage basins) are used to discharge collected water via infiltration into the subsoil where water seeps down to recharge groundwater. The basins and trenches are constructed similarly and are basically gravel-lined areas designed to provide seepage into the ground. Trenches can be used to provide zones of recharge to groundwater, diverted surface water, and/or treated groundwater.

Trenches or basins may require periodic cleaning to prevent clogging by silt and biological growth. A construction variation that avoids this maintenance problem is to use buried, perforated conduit (PVC, steel, or tile) surrounded by an envelope of gravel pack. This pipe network can then be covered with backfill. Seepage ditches of this type require little or no maintenance. They may be placed below the frostline, thereby avoiding the freezing difficulties encountered with open trenches. This technology may be useful for recharging treated groundwater and will be retained for inclusion during final system design.

2.2.3 Subsurface Drains

Subsurface drains include any type of buried conduit that conveys and collects aqueous discharges by gravity flow. Subsurface drains act somewhat like a line of extraction wells. They drain a continuous zone of influence so that groundwater within this zone flows toward the drain. Subsurface drains usually include these components:

- Drain pipe or gravel bed (conveys flow to a storage tank or well). Pipe drains are preferred for hazardous waste sites. Gravel bed or french drains and tile drains are used less frequently.
- Envelope (impermeable downgradient barrier--i.e., plastic sheeting that conveys flow from the aquifer to the drainpipe or bed).
- Filter (prevents fine particles from clogging the system).
- Backfill (brings the drain to grade, prevents ponding).
- Manholes or wet wells (collect flow and pump discharge to a treatment plant).

Drains perform many of the same functions as a continuous line of wells. They can contain or remove a plume, lower the groundwater table, and keep water away from the waste material. For soils of variable or low hydraulic conductivity and where contamination is shallow, drains are more cost effective than pumping.

Subsurface drains are technically feasible relative to the upper sand unit at the EEA because of its shallow depth. This is the groundwater collection alternative for the EEA, selected in the Phase I FS. The WEA and the depths to the middle sand unit on the EEA are too great for subsurface drain technology. Therefore, this technology is not further evaluated.

2.2.4 Containment Barriers

A containment barrier is a low-permeability cutoff wall or diversion installed below ground to contain and capture or redirect groundwater flow in the vicinity of a site. If properly built, and if materials of construction are compatible with the waste, this effective technology requires little or no maintenance.

The barrier is typically constructed by excavating a vertical trench and filling it with a bentonite-water slurry. Hydraulically, the slurry shores up the trench to prevent collapse and seals the walls with a filter cake of bentonite to prevent fluid loss to the surrounding soil.

At its base, the slurry wall is usually keyed into a notch in bedrock, a clay deposit, or other low-permeability layer. Good key-in is essential for creation of a complete containment barrier. Alternatively, the slurry wall may be left hanging,

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with no key-in at the base. Such a containment barrier can control floating contaminants but may not be effective for controlling groundwater flow, particularly if there is a downward hydraulic gradient.

The containment barrier may be located upgradient from the site (where it deflects groundwater flow around the site), downgradient from the site (where it provides maximum groundwater flow restriction), or completely surround the site.

Because the hydraulic gradient is downward in some areas at MSGS, a hanging containment barrier is not appropriate. Good key-in cannot be ensured due to the great depth to bedrock and the absence of a completely extensive and relatively shallow low-permeability layer. Therefore, containment barrier technologies are not evaluated further.

2.3 GROUNDWATER TREATMENT

2.3.1 Groundwater Treatment at the Surface

Groundwater treatment subsequent to groundwater extraction is technically feasible, assuming that groundwater extraction from the middle sand unit can be accomplished without causing unacceptable environmental and public health impacts resulting from inducing downward contaminant migration from the upper sand unit. Applicable technologies for groundwater treatment at the surface include air stripping, carbon adsorption, steam stripping, and offsite treatment.

2.3.1.1 Air Stripping. Air stripping is a mass transfer process that transfers volatile compounds in water to gas. It is usually carried out in a packed tower equipped with an air blower, employing the principle of countercurrent flow. Water flows down through the packing, while the air flows upward. The air, saturated with volatiles, exhausts through the top of the tower for treatment, if necessary. Volatile, soluble components tend to leave the aqueous stream for the gas phase.

Air stripping has found widespread use for effective removal of volatile organics from aqueous waste streams. It is cost effective for treatment of moderate to high concentrations of volatiles or as a pretreatment step for cleanup with activated carbon. Air stripping equipment is relatively simple. Startup and shutdown can be carried out quickly. The modular design of the packed towers makes air stripping well suited for hazardous waste site applications (USEPA, 1985b).

Because air stripping is based on mass transfer, the process is most efficient at higher concentrations. Removal efficiencies decrease with decreasing analyte concentrations. Vinyl chloride is a highly hydrophic compound identified as a chemical of concern. It may be readily removed by air stripping, but cannot be effectively treated by carbon adsorption. Therefore, air stripping will be retained for future consideration.

2.3.1.2 Carbon Adsorption. Carbon adsorption removes chemical contaminants from water by physical and chemical adsorption of organics onto the surface of carbon particles. Granular activated carbon (GAC) is most frequently used in wastewater treatment. For GAC treatment, groundwater is pumped through a bed of GAC, where close contact with carbon particles promotes contaminant adsorption. Carbon adsorption removes a wide range of organic contaminants and numerous inorganic contaminants. Adsorption is reversible, and the exhausted carbon can be regenerated in either an onsite or offsite thermal regenerator, though offsite regeneration by the carbon manufacturer is usually less costly. Spent GAC units also can be landfilled.

Carbon adsorption may be an effective method for the removal of contaminants to the parts per billion range. At high contaminant concentrations, the process may require frequent monitoring to track contaminant breakthrough. Operation costs are modest, but maintenance costs may be high for replacement of carbon and regeneration or replacement.

2.3.1.3 Utilization of Phase I System. The treatment system proposed by the Phase I FS involves treatment of extracted groundwater from the upper sand unit and the middle sand unit south of the swamp. With proper design, this system would also be effective for treating groundwater extracted from the units beneath the upper sand unit in the EEA. Contaminants found in the middle sand unit appear to have originated in the upper sand unit and, therefore, should be present in influent to the Phase I system. The addition of groundwater from extraction wells should not be detrimental to the functioning of the Phase I System. A distinct advantage would be the obvious cost saving by not operating two separate treatment units for the same site. Verification of treatability would need to be made using a pilot study or bench scale tests.

The design and layout of the system and extraction well piping would need to be coordinated with the designers of the Phase I system. This option obviously has advantageous economies of scale.

2.3.1.4 <u>Steam Stripping</u>. Steam can also remove organics from aqueous wastes. Steam stripping is a continuous, fractional distillation process carried out in a packed tower. Clean steam supplies direct heat to the tower. The contaminated steam condenses, and solvent and "stripped" effluent are the products. This technology is employed for treating aqueous waste contaminated with chlorinated hydrocarbons, aromatics such as xylenes, ketones such as acetone or methyl ethyl ketone, alcohols such as methanols, and high boiling point chlorinated aromatics such as pentachlorophenol. Steam stripping will treat less volatile and more soluble wastes than air stripping and can handle a wide concentration range (from less than 100 ug/l to 100,000 ug/l organics).

Because this technology requires the generation of steam, the process is energy-intensive and, therefore, costly. The condensed steam (solvent) will be contaminated and most likely hazardous and will require further treatment and/or offsite disposal. This technology is not as mobile or as commonly used as air stripping and carbon adsorption, and unless treatability studies indicate some compounds are especially recalcitrant, this process will not be considered further.

2.3.1.5 <u>Discharge to Surface/Pipe to Offsite Treatment Plant</u>. Discharge of extracted groundwater to surface streams or piping to offsite treatment plants is a potentially feasible technology for treating groundwater. Prior to discharge of groundwater to surface water bodies, it is generally necessary to evaluate the chemical nature of the groundwater relative to the assimilative capacity of the water body to provide for nonimpact on the water body. Controls to discharge, such as maximum allowable discharge rates and contaminant levels, frequently become requirements prior to authorization for discharge. An enforcement vehicle containing requirements such as those in a National Pollutant Discharge Elimination System (NPDES) permit may be required.

Alternatively, offsite treatment/disposal may be facilitated by piping (or sometimes trucking) of groundwater to an offsite treatment location such as a community wastewater treatment system. This technology is more feasible if a pipeline such as a sanitary sewer system is already in operation near the site.

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2.3.2 <u>In-Situ Treatment</u>

In-situ treatment technologies for groundwater include biological, chemical, and/or physical treatment. In-situ treatment technologies can be implemented without groundwater extraction, thereby inducing no additional downward leachate migration into the semiconfined water-bearing units. However, in-situ treatment is severely limited by the techniques available to deliver nutrients, reagents, microorganisms, oxygen, etc., to the geological formations of interest and to recover byproducts of treatment. Heterogeneous formations, such as those found at MSGS, are the most difficult settings in which to apply in-situ treatment technologies.

2.3.2.1 <u>In-Situ Biological Groundwater Treatment.</u> In-situ biological treatment of groundwater has been used to biologically degrade hydrocarbons and other biodegradable compounds in contaminated aquifers. The process, known as bioreclamation, is based on the concept of stimulating microorganisms to decompose the indicator chemicals by the addition of nutrients and oxygen. With the exception of petroleum hydrocarbons, biodegradation is still considered an unproven technology for use with mixed organics.

Even with nutrient addition, sufficient quantities of biodegradable constituents (as measured by biochemical oxygen demand (BOD), total organic carbon (TOC), or chemical oxygen demand (COD)) must be present to provide a substrate for microorganisms. Groundwater normally has very low levels of naturally occurring BOD. Data from Phase I sampling indicate a TOC level of approximately 2.9 ug/l for the deep monitoring well DMW-06. It is unlikely that the middle sand unit contains sufficient substrate to support a significant microbial population (Wagner and Kosin, 1985).

Therefore, this method of groundwater treatment is not recommended for use at the MSGS site.

2.3.2.2 <u>In-Situ Chemical Groundwater Treatment.</u> In-situ chemical treatment of groundwater involves the use of chemical additives to groundwater to mobilize, immobilize, or transform contaminants to a more manageable, or less toxic, form. The in-situ process would involve the surface application or injection of a chemical additive. Some additives may perform more than one of the treatment processes (i.e., immobilization, detoxification) simultaneously. For example, a flushing solution that mobilizes one contaminant may also precipitate, detoxify, or increase the toxicity of another contaminant. The specific in-situ chemical treatment methods applicable to the units at MSGS are presented in the following paragraphs.

The oxidation state of several organic contaminants in water can be raised (electrons are lost) through the use of an oxidizing agent. Common commercial oxidants are potassium permanganate, hydrogen peroxide, calcium or sodium hypochlorite, and chlorine gas (USEPA, 1985b). This process could be used to treat aromatic compounds and to partially strip chlorine atoms from the chlorinated compounds. If present, chloroform, being denser than water (approximately 1.5 times), is likely to be layered near the bottom of each water-bearing unit, which could make contact between an oxidizing agent and chloroform difficult.

The oxidation state of organics can be reduced through the use of catalyzed metals. This process has currently only been proven in theory for use with organics and will not be considered further for use at the MSGS site.

As mentioned previously, these processes require the delivery of a fluid to the subsurface. Hence, the limitations and applications of injection/extraction wells, drains, surface flooding, and spray irrigation are applicable to chemical in-situ treatment approaches. Other limitations include:

- Contaminated groundwater must be kept within the treatment area.
- Treatment reagents must not migrate away from the treatment area and become contaminants themselves.
- Uncontaminated groundwater must not be drawn into the treatment area and thus be contaminated during the extraction process.
- The potential adverse chemical reactions between soil/waste/water and the treatment reagents must be considered. In addition, the formation of precipitates due to treatment reagents may reduce soil permeability because of clogging.

The technical feasibility of in-situ chemical treatment is a complex function of site geology and hydrology, soil characteristics, waste characteristics, reagent chemistry, and the mode of reagent delivery to the subsurface. The application of these approaches to uncontrolled hazardous waste sites is conceptual or in the development stage. There are few, if any, engineering and design procedures currently in existence (Drake, 1987).

The complex hydrology of the site and the subsequent difficulty of treating the one unit without contaminating the lower units, coupled with the experimental nature of the treatment approaches, makes in-situ chemical treatment infeasible at the MSGS site.

2.3.2.3 In-Situ Physical Groundwater Treatment. Physical treatment involves the physical manipulation of the subsurface to immobilize or detoxify waste constituents. This field of treatment is relatively new, and most of the technologies are unproven. The technologies are best suited to areas of shallow contamination with permeable, homogeneous soil conditions. Due to the lack of design information and unproven nature of these technologies, in-situ physical treatment will not be considered for use at the MSGS site.

2.4 MANAGEMENT TECHNOLOGIES

Management technologies are those that provide for public and environmental protection without directly providing source remediation. They are frequently used during remediation construction and/or in conjunction with one or more source remediation technologies. These management measures are frequently arranged with the cooperation of State or local agencies; therefore, it is important to consider public institutional factors carefully before implementation.

2.4.1 Alternative Water Supplies/Drinking Water Treatment

The nearby residences and businesses adjacent to the site utilize well water as their primary water source. Therefore, various alternative water supplies and treatment options for existing supplies have been considered to present a complete range of technologies.

A large number of factors are involved in the consideration and design of alternative water supplies. This preliminary screening is intended to review and assess possible options for the site based only on technical feasibility. Design criteria are typically unknown at this point and are deferred to the detailed evaluation or to actual system design.

2.4.1.1 At-Tap Treatment. This treatment system could be more appropriately termed "well head," or point of use, treatment because the system would be installed on each water supply system between the well and the first point of use on the system. The system would typically consist of activated carbon tanks, ion exchange units, and/or an air stripper, depending on the analytes present. These units could be set up to accommodate individual wells, the combined influent from a series of wells, or a central supply area. Capital and operation and maintenance (O&M) costs would vary according to the system capacity and the number of units installed. This section will evaluate the feasibility of individual well systems.

The advantages of individual treatment units are:

- Because treatment systems would be installed only at wells where required, the water would be treated on an "as-needed" basis, and excess capacity, inherent in larger systems, would not be constructed.
- If development and new well installation are controlled in the area (by zoning or other land use ordinances), treatment could be limited to a relatively small number of wells and, therefore, would be comparatively inexpensive.
- If placed on individual wells, the system would not require a central storage or distribution system.
- This type of system can be readily adapted to an existing water supply system in a residence or small business and can be "tailored" to treat concentrations that may vary between adjoining properties.
- The system should prove reliable in providing potable water, being limited primarily by variations in influent concentrations and maintenance requirements.
- The system may be readily designed so that if system failure occurs due to mechanical failure or an unexpected peak of influent contamination concentration, only those served by the failed system would be affected.

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Disadvantages of this alternative are primarily results of the number and variation of systems installed:

- Each system would have to be individually monitored to determine analyte concentrations before and after treatment and daily water use.
- Because systems can be tailored to concentrations and daily flow, there can be a significant difference in design, carbon or resin use, and hence in maintenance of individual systems. This maintenance disparity could adversely impact operation and maintenance.
- Once installed, any system that encounters an unexpected concentration peak may require modification and/or be temporarily bypassed.

2.4.1.2 Centralized Treatment Systems. A centralized treatment system would provide water obtained from the potentially affected areas. An extensive transport/distribution system would not be required; however, water users in the potentially affected areas are relatively far apart, and infrastructure (capital) costs could be relatively high compared to individual treatment systems.

The EEA will have a treatment system onsite to treat groundwater extracted from the upper sand unit as part of the Phase I remediation. Although this system is presently only conceptual in design, it theoretically could be used to provide a central water supply system for residences if they were to require alternate water supplies. Because the system is necessary for remediation, the additional capital costs will be relatively low--basically upgrading the system design to meet drinking water standards and providing for storage, transport, and distribution. Additional data would be required on the flow capacity of the planned extraction trenches; possibly extraction wells would be required instead to meet user demands.

Although this system appears economically and technically feasible, experience shows that treated contaminated water may not be readily accepted by the public as an alternate water supply. As a result, we did not evaluate this alternative further.

2.4.1.3 Surface Water Sources. Sources of raw surface water near the site would be limited to Little Northeast Creek or Little Elk Creek. Either of these sources would require some treatment prior to distribution. In addition, they would require

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construction of storage, transport, and distribution systems. The extent of construction would be dependent on the proximity of the source of surface water to the affected residences. The nearby town of North East uses surface water from Little Northeast Creek for the public water supply system. The capacity of both Little Northeast Creek and Little Elk Creek would have to be evaluated in terms of water use needs. The treatment system for the upper sand unit proposed by the Phase I FS will possibly be discharging treated water to Mill Creek. This would affect flow rates for that surface water source.

These sources are technically feasible possibilities for alternate water supplies. Due to the extensive distribution involved, as well as the construction of an independent treatment system, this option is likely to be extremely expensive. Because the treatment and distribution of surface water as an alternative water supply will be at least an order of magnitude above other options in cost, it will not be recommended for detailed evaluation.

2.4.1.4 Extension of Existing Water Supplies. This option would involve extending the water supply system of Elkton to include affected residences.

Discussions with town officials indicate that this option is not currently feasible. Town restrictions, as well as water supply capacity, prohibit the construction of a pipeline from the town. Pipeline extensions may only be granted to service areas adjacent to the corporate limits of Elkton (the MSGS site is not), which may be annexed by the town. If local regulations or corporate limits change, this option could be reassessed (Elkton, 1988).

2.4.2 Water Use Controls

Water use controls are applicable at sites where drinking water supplies are shown to have been adversely affected by site contaminants. Water use controls would involve ordinances prohibiting the use of groundwater on or near the site. The measures would need to be arranged through the local agencies and officials and may meet with public dissatisfaction. Because other technologies involving permanent remediation are available, and offsite drinking water has not been shown to be impacted by the MSGS site, further evaluation of water use controls is not performed.

Although onsite development is not anticipated during the period of possible onsite treatment, water use controls to prohibit the onsite use of groundwater should be considered during final system design.

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2.4.3 Groundwater Monitoring

Future monitoring of groundwater quality is an applicable management technology to evaluate the effectiveness of implemented remedial options and to assess the potential need for future expansion or reduction of the scope of remedial efforts to control contaminant migration. Some monitoring programs for groundwater define contaminant concentrations (action levels) that trigger specific actions, such as implementation of groundwater treatment or installation of point-of-use water treatment systems at specified locations where groundwater is being used for domestic purposes. Components of monitoring system plans include identification of:

- Appropriate analytes.
- Sampling locations and frequencies.
- Schedule for implementing expanded or reduced efforts, should they become neccessary.

This management technology is particularly applicable at sites such as MSGS, where no evidence of offsite adverse groundwater impact is present and contaminant source remedial measures (Phase I ROD) are already scheduled. This management technology will be further evaluated in subsequent sections of this FS.

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TABLE 2-1

Summary of Preliminary Screening of Remedial Action Technologies

Response Action and Technology	Description	Comments	Potentially Applicable
Groundwater and Surface Water Collection/Control			
Pumping	Use of extraction wells to withdraw groundwater.		Yes
Surface Water Diversion and Control	Used to control the flow patterns of surface water and/or discharged groundwater. May be used to encourage infiltration. Technologies include infiltration trenches and basins.	No surface contaminant source at WEA. Surface water controls being implemented at EEA as part of Phase I ROD could be used to help encourage infiltration or treated water, flushing of unit, and to create hydraulic barrier against groundwater migration.	Yes*
Subsurface Drains	Use of perforated conduit laid in trenches to intercept groundwater plume and carry collected water via gravity flow to a central collection point.	Affected water-bearing units are too deep.	No
Containment Barriers	A vertical wall(s) of low-permeability material constructed underground to divert groundwater flow or minimize leachate generation and plume movement.	Affected water-bearing units are too deep. Not practical to install in bedrock.	No
Groundwater Treatment			
Extraction/Air Stripping	Remove volatile analytes by increasing water surface area and inducing volatilization.	Requires groundwater extraction, may not remove less volatile compounds.	Yes

TABLE 2-1 (cont'd)

Response Action and Technology	Description	Comments	Potentially Applicable
Groundwater Treatment (cont'd)			
Extraction/Carbon Adsorption	Remove hydrophobic analytes by passing water over bed of GAC.	Requires groundwater extraction.	Yes
Utilization of Phase I System	Utilize the proposed Phase I treatment system to treat contaminated groundwater from the middle sand unit.	Treatability study required. Because contaminants in the middle sand unit originate in the upper sand unit (addressed in Phase I), system should be compatible.	Yes
Extraction/Steam Stripping	Induce volatilization of analytes by heating influent to packed tower.	Costly, requires high O&M. Same level of removal may be achieved by less expensive technologies.	No
Discharge to Surface/ Pipe to Offsite Treatment Plant	Discharge groundwater to surface stream or pipe to offsite treatment location such as a sewage treatment plant.	Requires groundwater extraction. May require NPDES permit. Restrictions to groundwater pumping and discharge rates. Current discharge regulations are not likely to allow discharge of untreated water. No sewage treatment plants within an economical range.	No
In-Situ Biological Treatment	The stimulation of naturally occurring microorganisms to decompose indicator chemicals by the addition of nutrients and oxygen.	Indicator chemicals relatively nonbiodegradable. Low theoretical BOD. Low hydraulic conductivities, very heterogeneous.	No
In-Situ Chemical Treatment			
Oxidation	Surface application or injection of a chemical additive to raise oxidation state of a compound. Can be used to degrade aromatics and/or strip halogens.	May not degrade chloroform due to contact difficulty. Unproven, technically infeasible.	No

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TABLE 2-1 (cont'd)

Response Action and Technology	Description	Comments	Potentially Applicable
Groundwater Treatment (cont'd)			
Reduction	Surface application or injection of a chemical additive to reduce the oxidation state of a compound through the use of catalyzed metals.	Unproven for use with organics.	No
In-Situ Physical Treatment	Physical manipulation of subsurface to immobilize or detoxify waste constituents.	Best suited to shallow, homogeneous, permeable soil conditions. Unproven.	No
Management Technologies			
Alternative Water Supplies			
At-tap treatment	Individaul treatment units installed on each water supply system between the well and the first point of use on the system.	Relatively high O&M costs. Proven, reliable.	Yes
Centralized treatment system	Use of treated water withdrawn from the upper sand unit and treated as part of the Phase I remediation program.	Treated contaminated water may not be acceptable to public as drinking water supply.	No
Surface water sources	Withdraw, treat, and distribute surface water from Little Northeast Creek or Little Elk Creek.	Extremely high capital and O&M costs. Extensive pipe installation.	No
Extension of existing water supplies	Extension of water supply line from the town of Elkton.	Town ordinances and water supply capacity currently prohibit this option.	No

TABLE 2-1 (cont'd)

Response Action and Technology	Description	Comments	Potentially Applicable
Management Technologies (cont'd)			
Water Use Controls			
Prohibit groundwater use	Ordinances or zoning to prohibit the use of groundwater in the affected area.	Residents would require alternative water supply. Onsite restrictions should be considered during final system design.	Yes*
Prohibit new large-quantity water users	Ordinances or zoning to prohibit the construction of businesses or industries that would use large quantities of water.	Would help slow potential offsite migration by keeping groundwater withdrawal to a minimum.	No
Groundwater Monitoring	Monitor analyte concentrations in groundwater to evaluate need for expansion or reduction of scope of remediation.	Ensures protection of public health by monitoring effects of changing site conditions such as source controls under the Phase I ROD on concentrations of analytes.	Yes

*Will be retained for possible inclusion during final system design.

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3.0 DESCRIPTION OF REMEDIAL ACTION ALTERNATIVES

3.1 DEVELOPMENT OF ALTERNATIVES

In this section, applicable remedial technologies identified in Section 2.0 are assembled into various alternatives that address groundwater within the middle sand, lower sand, and bedrock water-bearing units at the site. Remedial alternatives for other media (i.e., surface water and soils) at the EEA were evaluated in the Phase I RI/FS. Soils and sediments associated primarily with the EEA will be addressed in a Focused Feasibility Study. At the WEA, remedial alternatives are not required for these media because the Phase II RI does not indicate that these media are sources of contamination.

In accordance with the NCP and USEPA guidance documents, alternatives are developed to provide a range of treatment alternatives varying in the degree of treatment, the amount of time to achieve complete treatment, and cost. Alternatives within this range differ in the type and extent of treatment used and the management requirements of treatment residuals or untreated wastes.

The USEPA requires that at least one alternative involve containment of the waste with little or no treatment but protect human health and the environment by preventing exposure and/or reducing the mobility of contaminants. In addition, a no-action alternative must be included (USEPA, 1988). Descriptions are developed for each alternative to enable detailed evaluations to be carried out in Section 4.0.

The preliminary screening in Section 2.0 indicated that the following technologies were applicable to remediation of the middle sand, lower sand, and bedrock units:

- Groundwater monitoring
- Groundwater extraction via wells
- Air stripping
- Carbon adsorption
- Ion exchange
- Phase I treatment system.

These technologies were combined to form the following alternatives:

A - No action

B - Onsite groundwater monitoring

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C - Offsite groundwater monitoring

D - Onsite and offsite groundwater monitoring

E - Onsite groundwater monitoring with offsite, point-of-use treatment (air stripping, carbon adsorption, and/or ion exchange)

F - Onsite and offsite groundwater monitoring with offsite, point-of-use treatment (air stripping, carbon adsorption, and/or ion exchange)

G - Onsite monitoring with onsite treatment using the Phase I treatment system

H - Onsite and offsite monitoring with deferred onsite treatment using the Phase I system and deferred offsite, point-of-use treatment (air stripping, carbon adsorption, and/or ion exchange)

I - Onsite monitoring with onsite treatment using a new treatment system (air stripping, activated carbon, and/or ion exchange)

J - Onsite and offsite monitoring with onsite treatment using a new treatment system (air stripping, activated carbon, and/or ion exchange).

Alternative C was screened from further consideration on the basis of public health impacts. This alternative would provide information on groundwater quality outside the boundary of the waste management area. Degradation in drinking water quality of offsite users would be detected only after exposure had occurred.

Alternative E was screened from further consideration on the basis of technical infeasibility. It would not provide a determination of which offsite wells were affected and by which constituents. Therefore, it could not be determined which offsite drinking wells required treatment systems.

Alternatives I and J were screened from future consideration on the basis of cost. These alternatives would be at least an order of magnitude more expensive than Alternative G, without providing any additional protection or remediation. Therefore, they will not be considered further.

The remaining alternatives have been numbered 1 through 6 and are described in detail in the following sections.

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3.2 ALTERNATIVE 1--NO ACTION

Alternative 1 fulfills the requirement that a no-action alternative be considered. This alternative is included for comparative purposes.

3.3 ALTERNATIVE 2--ONSITE GROUNDWATER MONITORING

Alternative 2 provides for an assessment of whether observed analytes within the confined groundwater units are decreasing in response to Phase I remedial measures and natural attenuation mechanisms. Documentation of this situation would facilitate evaluation of the appropriateness of terminating cleanup of upper and middle sand unit groundwater at the EEA associated with the Phase I ROD implementation.

Onsite wells to be monitored will include four new wells (MS-1, MS-2, MS-3, and LS-1) and seven existing wells (see Figure 3-1). These wells are located upgradient and downgradient along the boundary of the waste management area and provide monitoring of the middle and lower sand and bedrock units. The upper sand unit is excluded from the previous summary, because it will be closely monitored during implementation of the Phase I ROD.

In the middle sand unit, wells will consist of one existing well (DMW-07) and three wells (MS-1, MS-2, and MS-3) to be constructed. The location of MS-1 was selected to monitor the middle sand unit upgradient from the EEA. Upgradient monitoring was considered desirable in order to establish background groundwater conditions. MS-2 was located within the EEA near ponds P02 and P03, because these are known locations where wastes were disposed of in quantity. Therefore, this well will monitor for leakage through the upper silt and clay layer. MS-3 was located near seeps where water from the upper sand unit discharges at the surface and reinfiltrates into the middle sand unit; this well will monitor the middle sand unit for contamination resulting from these seeps. Its location is approximate; the actual location will be selected in the field on the basis of inspection of seep areas.

In the lower sand unit, wells will consist of three existing wells (D&M-06A, D&M-11, and DMW-03) and one well (LS-1) to be constructed. D&M-11 is located upgradient of the EEA and will serve as a background well. The other three wells are located downgradient of the EEA. D&M-06A and DMW-03 are in an area where head gradients are downward into the lower sand unit. This area is considered most favorable for contaminant migration from the middle sand unit to the lower sand unit. LS-1 is located closer to the EEA in order to detect contaminants that may have moved downward into the lower sand unit in the immediate area of the EEA. Although there is little direct evidence for downward migration from the EEA into the lower sand unit upgradient of this point, this well will provide early detection of such migration if it does occur.

In the bedrock unit, three existing wells (D&M-07, D&M-10, and D&M-12) will be monitored. D&M-10 is upgradient of the EEA and will serve as a background well. D&M-07 and D&M-12 are directly downgradient of the EEA. Construction of new bedrock wells was not considered necessary because of the generally low hydraulic conductivity of the bedrock, and because monitoring of the overlying middle and lower sand units will detect contamination should it move downward toward the bedrock.

Phase II monitoring is expected to be initiated in early 1990, based on a Phase II ROD in mid-1989 and a time allowance for design, design approvals, and construction of the new monitoring wells. Quarterly samples would be taken from the middle and lower sand unit wells and analyzed for TCL volatiles. These wells would be sampled annually for TAL metals. Bedrock wells would be sampled annually and tested for VOC's and metals. The scope of monitoring, such as parameters, frequency, duration, etc., will be reviewed and evaluated periodically.

This program would continue until 2 years after startup of the Phase I treatment system (currently projected as mid-1992, or approximately 4 years of monitoring). At this time, VOC sampling of the middle and lower sand units would be reduced to semiannually, until a total of 5 years has elapsed and the monitoring program is reevaluated.

For costing purposes, it has been assumed that the middle sand, lower sand, and bedrock units will be monitored annually for TCL VOC's and TAL metals for an additional 25 years.

The findings from this monitoring program will be forwarded to the appropriate USEPA and State of Maryland reviewers. Requirements for modifying the monitoring program may be evaluated during or before the 5-year review sessions, as necessary. Monitoring results will be reviewed and evaluated annually to determine overall groundwater conditions. The appropriate specifications (used for cost estimates) for the four new onsite monitoring wells have been determined to be as follows:

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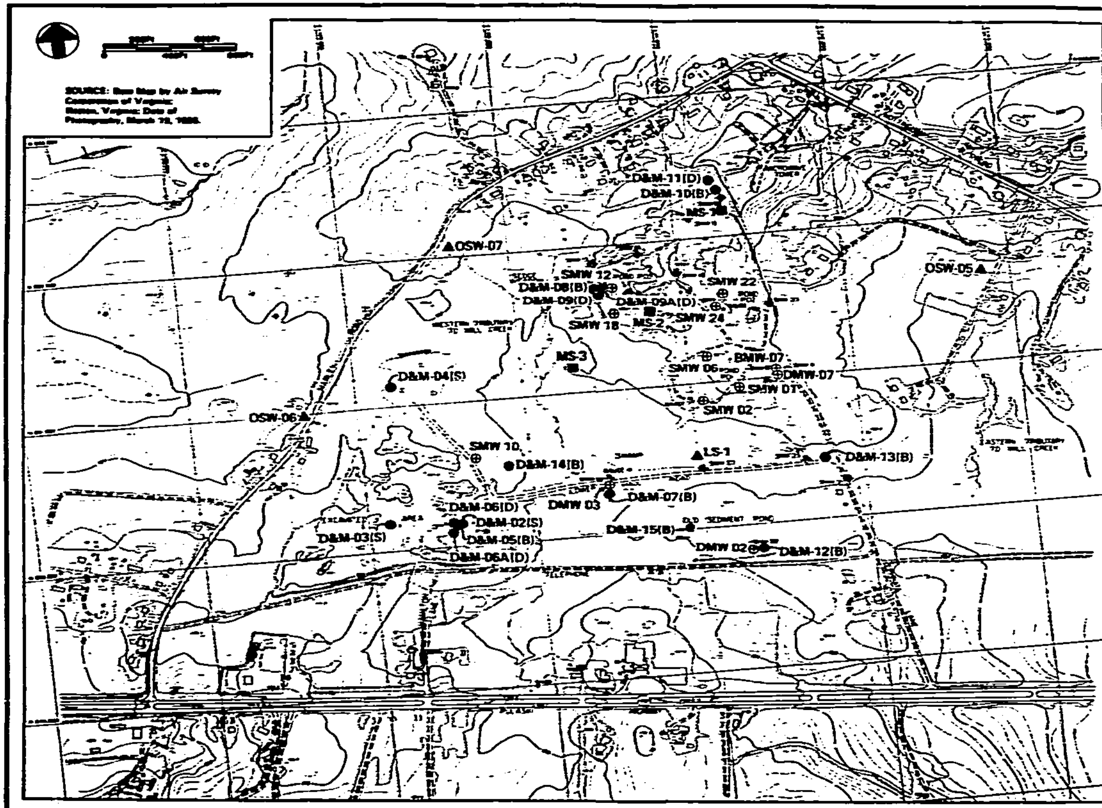
Well[a]	Approximate Depth (ft)	Screen Length (ft)	Diameter (in)
MS-1	120	40	4
MS-2	60	40	4
MS-3	40	30	4
LS-1	120	40	4

[a]See Figure 3-1 for well locations.

These depths and screen lengths were estimated on the basis of logs of nearby wells. Actual depths and locations will be selected in the field on the basis of subsurface information obtained during drilling. This information will be used in conjunction with logs of nearby existing wells to ensure that new wells are completed in the intended subsurface units. Actual screen lengths will also be selected in the field on the basis of the thickness of permeable sands that are penetrated during drilling. Well screens will penetrate most or all of the thickness of the permeable sands selected. Some screens will probably extend a few feet below the bottom of the sand, because it will probably be necessary to extend the boring a few feet into the underlying lower-permeability unit in order to verify that the lower contact of the sand has been reached. Other screens may extend a few feet above the top of the permeable sand in order to place the bentonite seal and the bottom of the grout within a low-permeability unit to prevent unintended grout migration.

Well MS-3 would be installed in an area where the upper silt and clay layer is thin or absent; consequently, the middle sand unit is at or near the surface. Therefore, no permanent large-diameter casing would be installed surrounding the 4-inch casing in MS-3. Conditions at LS-4 are more difficult to predict; therefore, we would assume that the middle sand unit is present near the surface, and would install an 8-inch steel casing to the bottom of the middle sand unit (or to a depth of 60 feet if the middle sand unit is not present at this location).

Drilling costs are based on actual 1988 costs from previous onsite well installations by Hardin-Huber, Inc. Drilling fluids and cuttings have been assumed to be nonhazardous. Cost estimates for disposal are based on 1988 quotes from Waste Conversion, Inc., for disposal of drummed fluids.



LEGEND:

- ● Well installed during Phase II
  - (S) Shallow well
  - (D) Deep well
  - (B) Bedrock well
- ⊕ Well installed during Phase I
  - SMW Shallow well
  - DMW Deep well
  - BMW Bedrock well
- ▲ Offsite Well (OSW)
- ■ New Monitoring Well in Middle Sand (MS)
- ▲ New Monitoring Well in Lower Sand (LS)

WELLS TO BE MONITORED

Middle Sand:
MS-1, MS-2, MS-3, DMW-07

Lower Sand:
LS-1, DMW-03, D&M-06A, D&M-11

Bedrock:
D&M-07, D&M-10, D&M-12

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FIGURE 3-1
APPROXIMATE LOCATION OF ONSITE MONITORING WELLS
(ALTERNATIVES 2, 3, AND 4)

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3.4 ALTERNATIVE 3--ONSITE AND OFFSITE GROUNDWATER MONITORING

Alternative 3 consists of onsite and offsite groundwater monitoring. The onsite monitoring portion of this alternative is identical in scope to the onsite monitoring program described for Alternative 2. Offsite monitoring would be conducted on an annual basis; samples would be analyzed for TCL VOC's and TAL metals. Offsite monitoring encompasses four wells serving both residences and businesses as listed in Table 3-1. Figure 3-2 illustrates the tentative locations of the proposed offsite wells to be monitored (onsite wells remain as indicated in Figure 3-1). The scope of monitoring, such as parameters, frequency, duration, etc., will be reviewed and evaluated periodically.

The locations of offsite wells to be monitored were selected to maximize the likelihood of detection of potential analytes from MSGS. Most of the locations are to the immediate south of MSGS, in the downgradient groundwater flow direction. The monitoring locations also were selected to cover the entire MSGS property to minimize the future possibility of groundwater analytes flowing between monitoring points. Access rights and permission to sample will have to be obtained from each well owner prior to finalizing the offsite well sampling program. As with the onsite treatment program, the monitoring schedule and number of monitored wells may be expanded (as necessary) to provide information on plume migration, and the monitoring schedule and scope will be reviewed every 5 years.

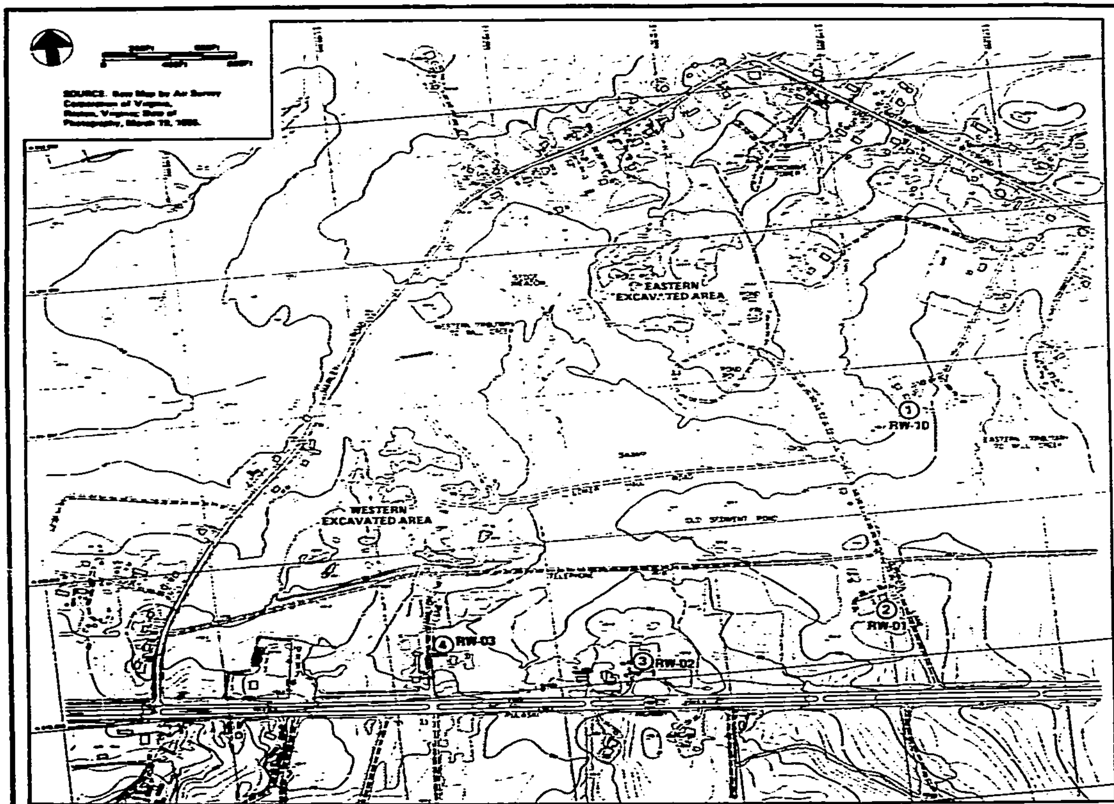
A large-volume groundwater user is included in the monitoring plan to account for the possibility that groundwater analytes might preferentially be drawn toward this location. Available groundwater monitoring data do not indicate that this is occurring.

TABLE 3-1

Offsite Groundwater Monitoring Locations

Well Designation	Facility Served	Location[a]/Comments	Depth (ft)	Screened Interval (ft)
RW-01	Residence	1,000 feet south of Old Sedimentation Pond, along Ephrata Lane (sampled in Phase I as RW-01)	72	67 to 72
RW-02	Business (large-volume user)	1,000 feet southwest of Old Sedimentation Pond, along U.S. Route 40 (sampled in Phase I as RW-02)	118	108 to 118
RW-10	Residence	1,500 feet southeast of EEA (shallow well sampled in Phase I as RW-10; owner has recent bedrock well)	65	60 to 65
RW-03	Residence	700 feet south of WEA, along Hamilton Lane (sampled in Phase I as RW-03)	114	109-114

[a]See Figure 3-2 for locations.



KEY:
1 Offsite Monitoring Well; for Description see Table 3-1

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FIGURE 3-2
LOCATION OF OFFSITE MONITORING WELLS

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3.5 ALTERNATIVE 4--ONSITE AND OFFSITE GROUNDWATER MONITORING WITH DEFERRED OFFSITE TREATMENT

Alternative 4 involves the use of onsite and offsite monitoring as described for Alternatives 2 and 3. In addition, if indicated by offsite monitoring data, offsite point-of-use treatment would be implemented. The decision process is shown in Figure 3-3.

Minor fluctuations of concentrations in onsite wells are expected in response to natural variations associated with sampling, analysis, site conditions, etc. Therefore, potential, statistically significant increases would be identified using an appropriate statistical test. This test would be applied to each of the units of concern being monitored (middle sand, lower sand, and bedrock units).

Information concerning the performance of the Phase I groundwater treatment system would be necessary to provide additional data for the onsite upper sand unit. These data include water quality data acquired after implementation of the Phase I ROD to evaluate the effect that treatment of groundwater in the upper sand unit at the EEA may have on groundwater quality in the underlying middle sand, lower sand, and bedrock units.

For offsite wells, detection of any of the contaminants of concern during a particular monitoring period would require immediate resampling of the affected offsite wells. Concurrently, bottled water for drinking purposes could be made available to the affected residence or business, as indicated.

If any of the contaminants of concern are detected at levels above MCL's again after resampling, and no obvious offsite sources (such as recent spills) are identified, then point-of-use activated carbon, air stripping, and/or ion exchange treatment systems would be installed at the affected wells. The type of system(s) installed would depend on the analytes found during monitoring. Highly soluble organics not amenable to GAC adsorption would require a small-scale point-of-use air stripper. These units have only recently become commercially available in a prepackaged form because of increasing concern over groundwater quality. They are identical in operation to the larger units. The system is normally placed within a housing just outside the home or, if clearance allows, within the basement or garage. Water would be pumped from the well by a normal submersible pump, through a booster pump (1/3 to 1/2 hp) to raise water pressure, to the top of the air stripper. Effluent then would flow into a fiberglass bladder pneumatic tank for storage until use. If groundwater has high particulates, a filter would be required prior to the air stripper. High iron levels can cause fouling of the air strippers and would require an iron removal filter.

The installation of an individual unit could be completed in approximately 1/2 to 1 day, providing that electrical service (110-volt, 15-amp fuse, duplex outlet) is already installed and operational.

If other organics are confirmed, an activated carbon unit would be utilized either with or without the air stripper. These units are usually installed either under the sink or in the basement. A separate tap would be installed on the sink specifically for drinking water and cooking. The GAC filters supply water on demand and do not require any storage capacity. Filters would require periodic backwashing to remove particulates (new models are available with process controls that automatically backwash on a regular basis).

The filters are in cartridge form and would be easily replaced. The units are subject to bacterial growth, so an ultraviolet disinfection unit would be placed before the GAC filter as a deterent. Based on recommendations from the State of Maryland (personal communication), two filters would be installed to provide a backup system.

The ion exchange system would be for metals removal. Either a cation or an anion resin (or both) would be used, depending on the metals present. These units are very similar in appearance, operation and installation to the GAC filter cartridges. They may be placed in series with the GAC filter and/or the air stripper.

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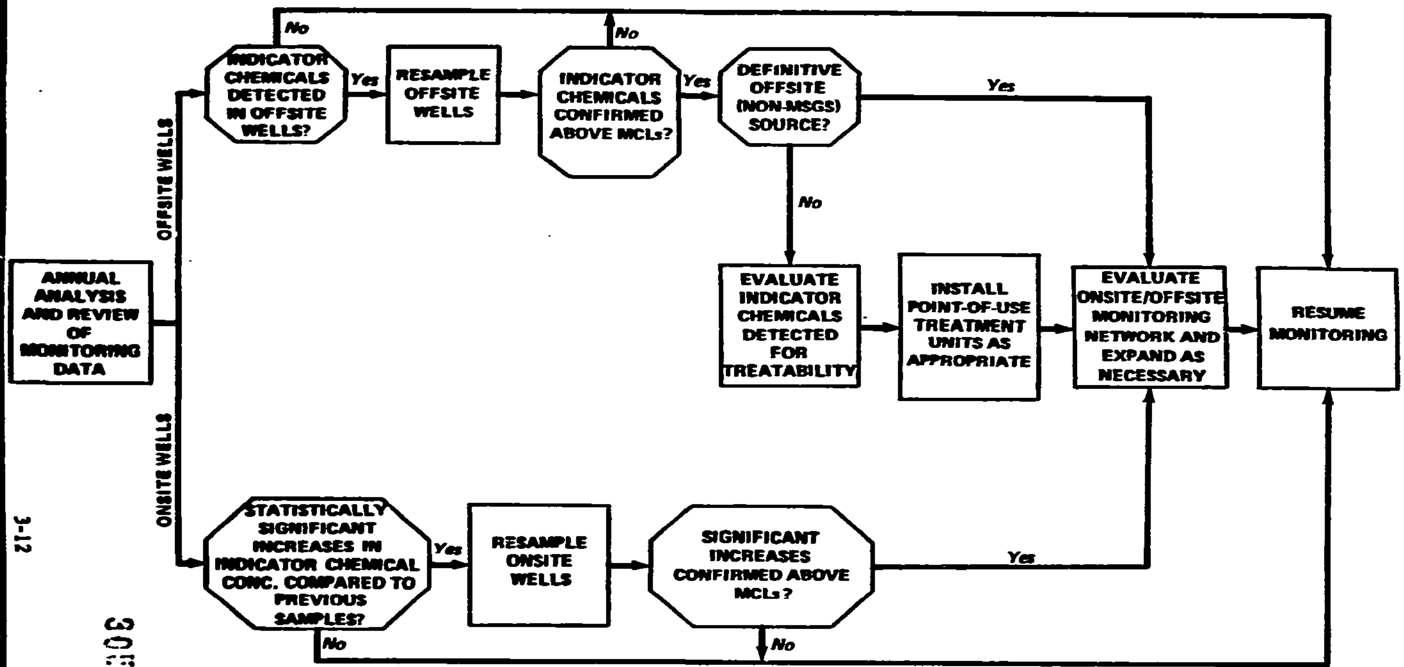

FIGURE 3-3
DECISION PROCESS FOR IMPLEMENTING POINT-OF-USE WATER TREATMENT
(ALTERNATIVE 4)

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3.6 ALTERNATIVE 5--ONSITE GROUNDWATER MONITORING WITH DEFERRED ONSITE TREATMENT

Alternative 5 involves onsite groundwater monitoring combined with (if necessary) onsite pumping and treating groundwater from the middle sand unit. The existence of contamination in the middle sand unit has been indicated from only one monitoring well. Additional wells (MS-1, MS-2, and MS-3, discussed in Alternative 2) should be installed to determine the extent of contamination in the middle sand unit before a remediation plan is formulated. If no contamination is found, only monitoring would be implemented. If groundwater treatment for this alternative is determined to be required, it would involve the use of the Phase I treatment system. The decision process for implementing onsite groundwater treatment is shown in the lower portion of Figure 3-5 (Section 3.7), which is an expansion of Figure 3-3 to include onsite treatment.

Minor fluctuations of concentrations in onsite wells are expected in response to natural variations associated with sampling, analysis, site conditions, etc. Therefore, potential, statistically-significant increases would be identified using an appropriate statistical test. This test would be applied to each of the units of concern being monitored (middle sand, lower sand, and bedrock units).

Information concerning the performance of the Phase I groundwater treatment system is necessary to provide for a detailed evaluation of this alternative. These data include water quality data acquired after implementation of the Phase I ROD to evaluate the effect that treatment of groundwater in the upper sand unit at the EEA may have on groundwater quality in the underlying middle sand, lower sand, and bedrock units. Also, the method of disposal (gravity outfall line to discharge point south of the Old Sedimentation Pond or discharge into the onsite ponds) of treated effluent from the Phase I treatment system may reduce or increase recharge to the unconfined portion of the middle sand unit along the western tributary of Mill Creek and at the Sedge Meadow Area. This would impact design alternatives for extracting groundwater from the units underlying the upper sand unit.

The groundwater treatment portion of this alternative may have negative impacts on the groundwater quality within the confined units if it is implemented

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before the contaminant sources affecting the upper sand unit, sediments, and soils at the EEA are removed or controlled (i.e., remedies have been successfully implemented). Lowering of the hydraulic head by pumping from the middle sand unit may accelerate the rate of downward migration/infiltration of contaminated near-surface groundwater.

The extent to which groundwater pumping could cause contaminant migration from the upper sand unit at the EEA, causing additional contamination of the underlying units, depends somewhat on the continuity and low hydraulic conductivity of the upper confining clay that separates the upper sand unit from the underlying units. Well-defined groundwater seeps at the surface where the upper confining clay crops out and the logs of borings from the EEA suggest that the upper confining clay probably forms an effective barrier, and direct leakage downward through this confining clay may not be the dominant pathway for induced leachate migration.

The most likely pathway for induced leachate migration is from the areas of the groundwater seeps (Sedge Meadow Area, area between pond P01 and the swamp, and the area east of pond P02). Lowering of the hydraulic head within the middle sand unit at these locations may encourage infiltration of contaminated seepage (discharging from the upper sand unit) directly into the middle sand unit, which is unconfined in the vicinity of these seeps.

The likelihood of this seepage occurring could be minimized by utilizing infiltration trenches or basins. These can be sited to encourage groundwater movement back toward the extraction wells, thus flushing out contaminants from the aquifer. In addition, this selective discharge to certain areas may produce a hydraulic barrier tending to limit migration away from the EEA.

If the rate of induced contaminant influx exceeds the rate of contaminant removal by groundwater treatment and other natural attenuative mechanisms, net groundwater quality will deteriorate. Contaminant removal rates from the confined/semiconfined water-bearing units at MSGS due to groundwater pumping/treatment are estimated to be low because of the poor water-producing capacity (low transmissivity) of these units. Simultaneously, the reduction of hydraulic heads in response to pumping is estimated to be high because of the low transmissivities. The combination of a low rate of contaminated groundwater removal and high potential for head reduction indicates that groundwater pumping

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and treatment from the middle sand unit may induce the spread of contamination if it is implemented before the leachate source in the upper sand unit at the EEA is controlled or limited.

Pumping and treatment of groundwater from the middle sand unit at MSGS should only be considered for implementation after the potential contaminant sources within upper sand unit groundwater, soils, and sediments at the EEA have been eliminated or controlled (i.e., remedies have been successfully implemented) and if the onsite groundwater monitoring shows an increase in analyte concentrations in the deeper water-bearing units, despite implementation of the Phase I groundwater treatment system.

Three groundwater extraction wells (EW-1, EW-2, and EW-3) would be used (see Figure 3-4) and placed approximately in the area of the three ponds. The wells would be located near the ponds that are believed to be principal source locations for contaminants. Groundwater extraction near sources would allow capture of contaminants before they become excessively diluted during groundwater transport. If other, more concentrated sources are discovered during remedial activities before installation of extraction wells, it may be desirable to relocate one or more of the extraction wells closer to such sources.

The number of wells was selected based on several considerations. Because of the small yield obtained from many of the monitoring wells, it was considered likely that one or two wells might not recover treatable quantities of groundwater. Providing only two wells appeared undesirable from the standpoint of system reliability, because damage to either well would reduce system capacity by roughly half and would leave no backup well. Thus, three wells appeared to be the minimum number of wells desirable. Modeling (described in Appendix A) confirmed that three wells could reasonably be anticipated to capture groundwater from the middle sand unit beneath most of the EEA. This number also allowed pairing an extraction well with each of the ponds. The actual number of extraction wells required will have to be determined by conducting pumping tests on the wells as they are installed to determine well yields and groundwater capture areas.

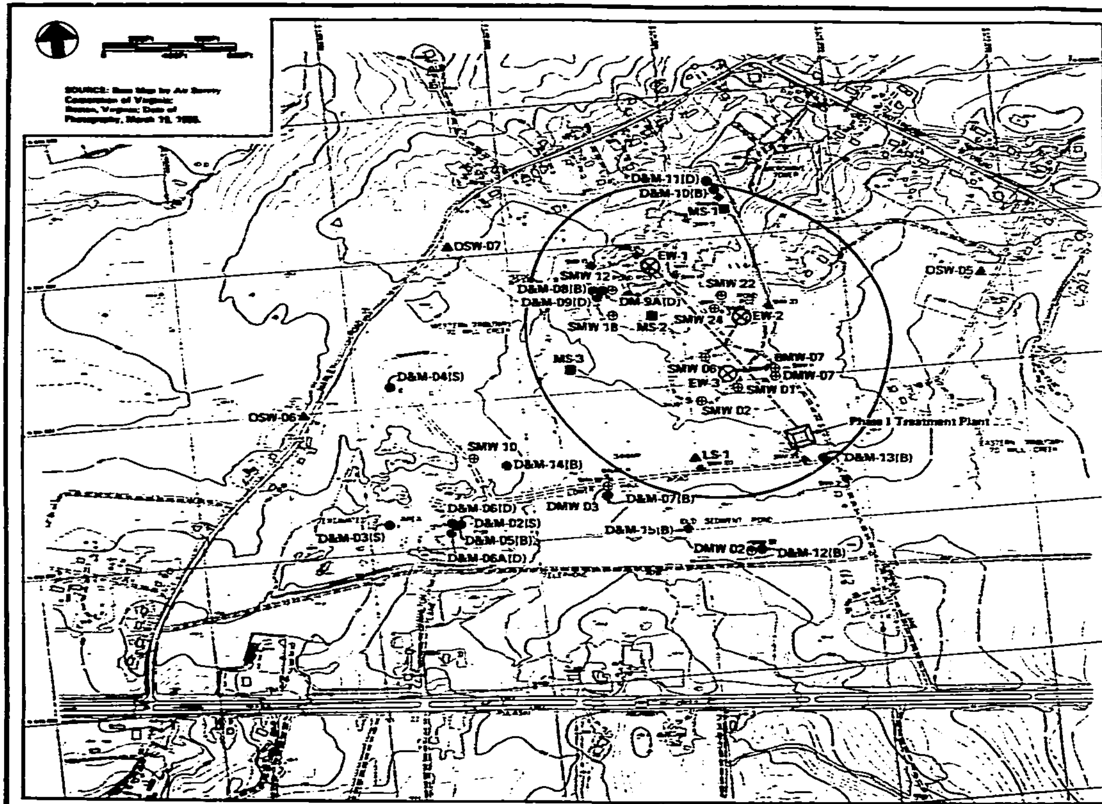
The wells (EW-1, EW-2, and EW-3; see Figure 3-4) would be 6-inches in diameter and approximately 70, 40, and 80 feet, respectively, in total depth at the anticipated locations near the ponds. They would be screened through the entire thickness of the middle sand unit in order to maximize potential yield. Actual well depths and screened intervals may vary and will be determined during drilling. The 6-inch well diameter was selected (compared with the 4-inch wells used for monitoring) to increase potential yield, to allow installation of larger pumps if justified by well yields, and to simplify installation of monitoring and control equipment. Groundwater from the wells would be piped to the Phase I treatment system via 4-inch PVC lines buried below the frost line. After treatment, water would be discharged as determined in the Phase I ROD.

The middle sand, lower sand, and bedrock unit monitoring wells would remain as indicated in Alternative 2. A summary table of approximate well specifications is presented below:

Well[a]	Unit[b]	Use	Depth (ft)	Screen Length (ft)	Diameter (in)
EW-1	MS	Pump	70	30	6
EW-2	MS	Pump	40	20	6
EW-3	MS	Pump	80	40	6

[a]See Figure 3-4 for well locations.
[b]MS = Middle Sand

The extraction wells would have an estimated drawdown of 10 feet or more. The groundwater capture area estimated on the basis of the modeling described in Appendix A is indicated in Figure 3-4. This area corresponds to the area within which modeled drawdown--resulting from combined pumping from all three wells--was 3 feet or greater. This drawdown was selected to define the capture area, because it was large enough to reasonably ensure that groundwater from this area (and upgradient) would be captured by the pumps. The production rate from each well is estimated at approximately 10 gallons per minute (gpm); this rate will depend on local conditions at the well sites and is only an order-of-magnitude estimate.



LEGEND:

- ● Well installed during Phase II
  - (S) Shallow well
  - (D) Deep well
  - (B) Bedrock well
- ⊕ Well installed during Phase I
  - SMW Shallow well
  - DMW Deep well
  - BMW Bedrock well
- ▲ Offsite well (OSW)
- — Piping
- ⊗ Extraction Well (EW)
- ■ New Monitoring Well in Middle Sand (MS)
- ▲ New Monitoring Well in Lower Sand (LS)
- — Estimated Extent of Groundwater Capture Area of Extraction Wells From Model

See Figure 3-1 for list of wells to be monitored.

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FIGURE 3-4
APPROXIMATE LOCATION OF ONSITE MONITORING AND EXTRACTION WELLS (ALTERNATIVES 5 AND 6)

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3.7 ALTERNATIVE 6--ONSITE AND OFFSITE GROUNDWATER MONITORING WITH DEFERRED ONSITE AND OFFSITE TREATMENT

Alternative 6 involves the use of onsite and offsite monitoring as described in Alternatives 2 and 3. In addition, if indicated by monitoring data, onsite and/or offsite point-of-use treatment would be implemented. Onsite treatment (if necessary) would involve pumping and treating groundwater from the middle sand unit as described for Alternative 5. Offsite treatment (if necessary) would involve point-of-use treatment systems. The details of these systems are described in earlier sections.

The decision process for implementing onsite and/or offsite point-of-use water treatment is shown on Figure 3-5, which is an expansion of Figure 3-3 to include onsite treatment. The addition of onsite treatment would not materially change the decision process. An initial decision to install either onsite or offsite point-of-use water treatment would be based on the results of the respective monitoring. Detection and confirmation of indicator chemicals at concentrations above MCL's in offsite wells would result in installation of appropriate point-of-use treatment units at the affected locations. The network of offsite monitoring wells would be evaluated in view of the location and water-bearing unit of the affected well(s) and the concentration(s) of indicator chemicals detected. Changes would be made to the network (as necessary) prior to the resumption of monitoring.

Onsite wells would be monitored for statistically-significant increases in indicator chemical concentrations compared to previous samples. If significant increases are encountered and confirmed at levels above MCL's, onsite treatment would be initiated. Both the onsite and offsite monitoring networks would be reevaluated at that time. In addition, both monitoring networks would be reevaluated, especially in terms of scope and schedule, every 5 years.

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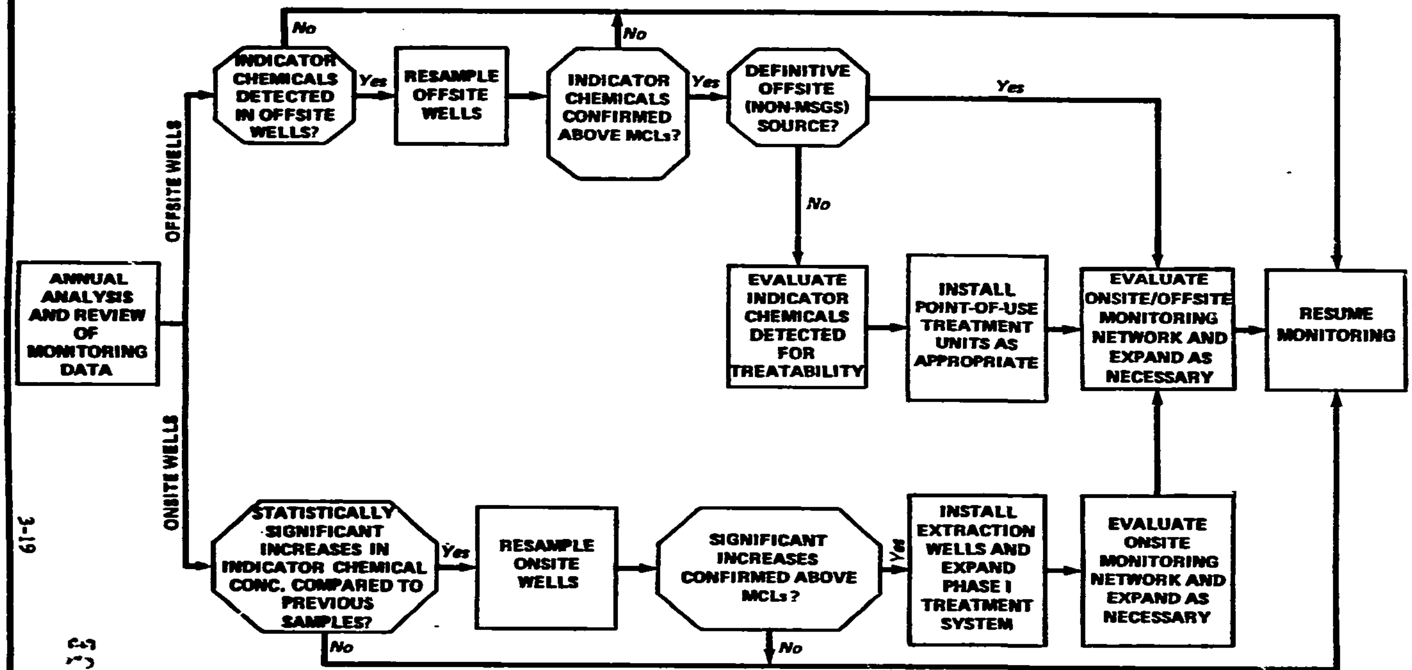

FIGURE 3-5
DECISION PROCESS FOR IMPLEMENTING ONSITE AND/OR OFFSITE WATER TREATMENT
(ALTERNATIVES 5 AND 6)

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4.0 DETAILED ANALYSIS OF ALTERNATIVES

4.1 EVALUATION CRITERIA

Each remedial action alternative carried through the detailed analysis will be evaluated based on the general categories of technical feasibility, environmental and public health impacts, regulatory aspects, and cost. These criteria, in turn, involve several components designed to reveal the overall applicability of the alternative.

The alternatives will be compared on the basis of this screening. The USEPA considers the most crucial criteria to be technical feasibility and implementability; followed by environmental and public health, overall protectiveness, long- and short-term effectiveness and permanence; regulatory compliance; and cost. Section 5.0 summarizes the results of this screening and presents the recommended alternative.

4.1.1 Technical Feasibility

The technical feasibility of the alternatives is based on four factors (outlined in the following sections). These criteria are intended to evaluate the technical factors of the physical construction, implementability, operation, and maintenance of the alternative.

4.1.1.1 Performance. Performance is assessed on the basis of effectiveness and useful life. The potential effectiveness of process options in handling the estimated areas or volumes of media and meeting the contaminant reduction goals identified in the general response actions, relative to other processes within the same type of technology, is evaluated. This evaluation applies primarily to the ability of treatment technologies to reduce contaminant levels in the various media. It also assesses the ability of some collection/removal systems to sufficiently recover contaminated media for subsequent treatment.

Effectiveness, in turn, is evaluated based on the capability of the alternative to meet the remedial objectives. "Useful life" is defined as the length of time that effectiveness can be maintained. At the end of the period of useful life, either the overall remedial objectives (i.e., cleanup criteria) will have been met, or the particular system component will no longer be effective in further reducing contaminant concentrations. An accuracy of no more than ±50 percent can be

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assumed for the estimated useful life of each process. Useful life should not be confused with the "functional period of performance," which refers to the life of equipment before replacement is necessary.

4.1.1.2 Reliability. Reliability is assessed on the basis of demonstrated performance and O&M requirements. Considerations include the potential for poor performance or failure of the system (or its components), the capacity of the system to accommodate variations between design criteria and actual field conditions, operational complexity, monitoring requirements, and the frequency of maintenance.

4.1.1.3 Implementability. The degree of implementability of a system is determined by the ease of installation, the time required to implement the technology, and the time required (after installation) for the technology to become effective. In addition, availability of equipment and special services (e.g., storage and disposal facilities) and the ease with which the system can be monitored will be evaluated.

4.1.1.4 Safety. Safety is evaluated in terms of the risk to environmental and public health in the event of system failure and in terms of the safety of workers, the public, and the environment during initial system construction and subsequent operation (USEPA, 1985a).

4.1.2 Environmental and Public Health

The environmental and public health screening evaluates both long- and short-term effectiveness of the alternative and risks from the installation and operation of a system. Risks in the event of system failure are discussed under performance. For public health, risks could include noise or air pollution, odor, use of natural resources, aesthetics, and interference with public services or local businesses. Environmental risks could include acute or chronic toxic effects on plant or animal life, breeding cycle disruptions, alteration of wildlife habitat, and threats to protected plant and animal species. In addition, the degree of protection of human health and the environment provided by the alternative will be evaluated.

4.1.3 Compliance With ARAR's

Alternatives will be considered on the basis of compliance with ARAR's; air, noise, and water standards; land use and zoning; and Federal, State, and local laws.

ARAR's are requirements, criteria, or limitations promulgated under Federal or state law that address a pollutant, action, location, or other circumstances at a site. USEPA guidance offers the following illustrative categories of ARAR's:

- Ambient or chemical-specific requirements--These set health- or risk-based concentration limits or ranges for specific substances in various environmental media (e.g., MCL's for public drinking water and National Ambient Air Quality Standards (NAAQS) for air quality). If a given chemical has more than one such requirement, the more stringent ARAR should be complied with. Because relatively few chemicals are covered by such preestablished requirements, USEPA's ARAR guidance stipulates that it may frequently be necessary to turn to chemical-specific advisory levels, such as carcinogenic potency factors or reference doses, to establish cleanup standards.

- Performance, design, or other action-specific requirements--These set controls or restrictions on particular kinds of activities related to the management of hazardous substances (e.g., Clean Water Act (CWA) pretreatment standards for discharges to publicly-owned treatment works (POTW)). These requirements are not chemical-specific, but are specific to given remedial actions. However, they may specify levels for residual or discharged chemical concentrations (or methods for establishing those levels).

- Locational requirements--These set restrictions on activities depending on characteristics of the site or its immediate environs (e.g., Federal and state siting laws and 100-year floodplain ordinances).

In general, onsite remedial actions are required to comply with only the substantive aspects of ARAR's--not the administrative aspects, such as obtaining permits or recordkeeping. The RI/FS, ROD, and design documents for a site should demonstrate full compliance with all substantive requirements that are ARAR's.

The following is a list of ARAR's potentially applicable to the MSGS site:

- Clean Water Act (CWA)
    - NPDES Requirements (40 CFR Parts 122-124)

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- Safe Drinking Water Act
    - MCL's (40 CFR Parts 141 and 143)
- National Emission Standards for Hazardous Air Pollutants (NESHAP)
- Occupational Health and Safety Administration (OSHA) Requirements
    - Requirements for workers at remedial action sites (29 CFR Part 1910)
- U.S. Department of Transportation (DOT) Regulations (49 CFR Parts 170-179)
- Response in a floodplain or wetlands (40 CFR Part 6, Appendix A, and Executive Orders 11988 and 11990)

The application of the regulations is described for each remedial alternative considered in this section.

4.1.4 Cost

Cost estimates will be presented with each alternative based on available manufacturers' information, literature values, and experience. The cost analysis summarizes the preliminary estimated costs of each alternative, reviews the major cost-related items, and discusses important considerations in the cost analysis. Present worth analyses will be performed using a discount rate of 10 percent for the life of the alternative to compare the costs of different remedial action alternatives on a common basis. All costs will be estimated in 1988 dollars and rounded to the nearest hundred dollars. Costs are considered to be accurate to +50/-30 percent. Where applicable, estimates will be broken down into construction (capital) costs and O&M costs. Total capital costs will be calculated by assuming construction contingencies of 15 percent and design, engineering, and construction management at 25 percent. O&M costs include 20 percent for overhead and contingency. These costs are preliminary order-of-magnitude estimates used for alternative comparative purposes only. A more detailed cost estimate of the recommended remedial action alternative ultimately will be prepared during the design planning.

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4.2 ALTERNATIVE 1--NO ACTION

4.2.1 Technical Feasibility

Because the no-action alternative would not require any operational components, the four technical feasibility screening criteria cannot be reasonably applied. The quantity and toxicity of the compounds present would continue to migrate and decompose influenced only by the present gradients and groundwater movement.

4.2.2 Environmental and Public Health

Because no remedial measures would be taken under this alternative, risks to environmental and public health would be influenced by the present hydrology and geology and by the implementation of the Phase I ROD. With the source removed and treatment instituted, the concentrations of compounds in generated leachate from the upper sand unit should decrease. Compounds already in the upper and middle sand units could continue to migrate downgradient and leach/seep into the middle and lower sand units until the upper sand unit is remediated. Thus, with the passage of time, the residual risk may increase before decreasing.

4.2.3 Compliance With ARAR's

The no-action alternative would be in violation of the CWA and/or the Safe Drinking Water Act, because standard exceedances have been observed onsite. As stated before, this alternative is primarily for comparison.

4.2.4 Cost

The no-action alternative would incur no direct capital or O&M costs.

305631

4.3 ALTERNATIVE 2--ONSITE GROUNDWATER MONITORING

4.3.1 Technical Feasibility

This alternative would serve to provide documentation of existing and future conditions at the site. Although monitoring alone would not provide any reduction of toxicity, mobility, or volume of compounds, it would provide a tracking system to reflect changes in groundwater conditions due to attenuation, dilution, or the Phase I treatment system. For costing purposes, a useful life of 30 years has been assumed, though the system could be maintained indefinitely at a relatively low cost, if necessary.

For the purposes of monitoring, the well system would be reliable with low O&M costs--basically well-purging pump replacement on an as-needed basis. The major potential system components susceptible to failure would be the purge-pumps and their associated electrical system. One other potential "system failure" could be low production rates for the wells, thereby making purging for sampling difficult.

The wells for onsite monitoring would be the 11 new and existing wells described in Section 3.3. Installation and development of new wells is expected to take approximately 8 to 10 weeks. Possible delays in installation could be caused by the following:

- Drill rig or mechanical failures
- Low production wells that must be relocated
- Driller must meet Health and Safety Training requirements for onsite work, thus limiting the available pool of drillers to those who are specifically trained for this type of work.

The installation of the new onsite monitoring wells should pose a very low health risk to the public. All work would be done onsite, and cuttings and well development water would be tested and disposed of appropriately. Well installation is noisy and can be messy (mud, cuttings, etc.), but should not adversely impact wildlife in terms of chemical exposure; no endangered or protected species are known to inhabit the site. Noise and dust levels may be temporarily raised during actual drilling.

305682

4.3.2 Environmental and Public Health

This alternative would pose minimal or no short-term risk to public health or the environment. The only risk posed by the site at present was determined by the EA to be a potential, worst-case, future-use risk posed by use of the middle sand unit groundwater. The monitoring of wells tapped into the middle and lower sand units should not affect either the public or the environment, except during installation.

Because this alternative provides no direct remediation, a decrease in analyte concentrations would only occur via institution of the Phase I ROD and natural attenuation and dilution. Until the Phase I treatment is completed (i.e., the shallow groundwater is remediated), contaminants will continue to leach/seep from the upper sand unit to the lower units. Thus, with the passage of time, the residual risk may increase before decreasing.

Remedial action objectives (or cleanup criteria) are based on human risk factors. Therefore, it could take an indefinite amount of time for the levels to be met in the onsite monitoring wells. Once the source removal is complete and Phase I treatment has stabilized, levels in the middle sand unit should begin to decrease due to natural mechanisms.

Residual risk from this alternative would presently be at the level specified in the EA. With the passage of time and implementation of the Phase I ROD, these risks may decrease. The actual numerical residual risk at any given future time cannot be determined without significant groundwater modeling and additional data collection, which are beyond the scope of this report.

Installation and operation of this alternative would pose only minimal risk to onsite workers from exposure to sediment and groundwater. Public health and the environment should not be significantly or adversely affected by well installation and sampling.

The alternative would provide no direct protection of human health or the environment, except by providing information on chemical fate and transport.

4.3.3 Compliance With ARAR's

This alternative, as with no action, would presently be in violation of the Safe Drinking Water Act and/or the CWA, because MCL exceedances have been documented onsite in the middle sand unit. Other ARAR's--Clean Air Act and OSHA Regulations--would be complied with as specified in the remedial action work plan and the health and safety plan. Provisions for air quality monitoring and worker protection would be specified in these documents.

4.3.4 Cost

This alternative proposes the monitoring of 11 onsite wells as described in Section 3.3 (see Figure 3-1) that would provide samples representative of the middle sand, lower sand, and bedrock units. This schedule is outlined below and could be revised at any time with the approval of all necessary regulatory authorities. The scope and schedule will, at a minimum, be evaluated every 5 years. The scope of monitoring, such as parameters, frequency, duration, etc., will be reviewed and evaluated periodically. The costs associated with onsite groundwater monitoring are outlined in Table 4-1 and are based on quarterly sampling for TCL VOC's and annual sampling for TAL metals for the middle and lower sand unit wells for 4 years, followed by biannual sampling for TCL VOC's and annual sampling for metals for 1 year. After this, annual sampling for VOC's and metals is assumed to continue for an additional 25 years. Bedrock wells would be sampled annually for VOC's and metals for all 30 years. The following wells (locations shown in Figure 3-1) would be sampled:

- Middle Sand Monitoring Wells

  MS-1, MS-2, MS-3, and DMW-07

- Lower Sand Monitoring Wells

  LS-1, D&M-06A, D&M-11, and DMW-03

- Bedrock Monitoring Wells

  D&M-07, D&M-10, and D&M-12

This alternative has a capital cost of approximately $79,900 incurred over 30 years and an annual O&M cost of approximately $43,900. The net present worth of this alternative at a discount rate of 10 percent for 30 years is $464,100.

305684

TABLE 4-1
Cost Estimate for Onsite Groundwater Monitoring
Alternative 2

Construction Costs

Item	Rate ($)	Unit	Cost (1988 $)
• Well Installation (MS-1, MS-2, MS-3, LS-1)			
Mobilization/demobilization	500	—	500
Drilling 12" hole for steel surface casing (MS-1, MS-2, LS-1)	24/ft	106 feet	2,500
8" steel surface casing, installed and grouted (MS-1, MS-2, LS-1)	42/ft	100 feet	4,200
Flushing surface casing	165/hr	2.5 hr/well	1,200
Drilling 8" hole	18/ft	250 feet	4,500
Installation of 4" well[a]	24/ft	258 feet	6,200
Filling borehole below well tip	165/hr	1 hr/well	700
Well covers, steel, locking	300 each	4 covers	1,200
Drums for drill fluid	65/dr	30 dr/well	7,800
Fill drums	165/hr	2 hr/well	1,300
Decontamination of equipment	165/hr	6 hr/well	4,000
Well development	120/hr	5.5 hr/well	2,600
Standby	165/hr	2 hr/well	1,300
Disposal of drilling fluids	65/drum	30 dr/well	7,800
Transportation of drilling fluids for offsite disposal[b]	500/load	2 loads	1,000
Sampling and analysis of drilling fluid[c]	1005/sample	2 samples/well	8,000
Well surveying	200/well	4 wells	800
Well Installation Subtotal			55,600

TABLE 4-1 (cont'd)

Item	Rate ($)	Unit	Cost (1988 $)
CONSTRUCTION SUBTOTAL			55,600
CONSTRUCTION CONTINGENCIES (15%)			8,300
TOTAL CONSTRUCTION COST			63,900
DESIGN, ENGINEERING, AND CONSTRUCTION MANAGEMENT (25%)			16,000
TOTAL CAPITAL COST			79,900
Annual O&M Cost			
• Sampling Costs			
Sample analyses - volatiles[c]	450/sample	10/event	18,000
Sample analyses - metals[c]	350/sample	8/yr	2,800
Containers and shipping	85 each	6/event (avg)	2,000
Labor[d]	2,500/event	4 events	10,000
Equipment and equipment rental[e]	400/event	4 events	1,600
Report preparation and sampling management	400/event	4 events	1,600
Sampling Subtotal			36,000
• Sampling Equipment (5-year replacement)			
Submersible pumps	300 each	1 pump	300
Miscellaneous	25/well	11 wells	300
Equipment Subtotal			600

TABLE 4-1 (cont'd)

Item	Rate ($)	Unit	Cost (1988 $)
OPERATION AND MAINTENANCE SUBTOTAL			36,600
CONTINGENCY AND OVERHEAD (20%)			7,300
TOTAL ANNUAL O&M COST			43,900
NET PRESENT WORTH[f]			464,100

[a] Includes installation of well, screen, sand pack, bentonite, and grout to surface.
[b] Waste Conversion, Inc., 1988.
[c] CLP TCL volatiles and/or TAL metals.
[d] Includes per diem.
[e] Includes vehicle, generator, field supplies, etc.
[f] 30 years, 10%.

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4.4 ALTERNATIVE 3--ONSITE AND OFFSITE GROUNDWATER MONITORING

4.4.1 Technical Feasibility

This alternative is similar in technical feasibility to the onsite monitoring alternative. The useful life of the system would remain at 30 years and could be maintained at a reasonable cost. Because existing residential or commercial wells are maintained by the residence owners, the O&M requirements of this alternative will be similar to Alternative 2. The simplicity of this alternative would make it reliable and easy to implement.

Safety hazards generated by well installation would be eliminated through the use of existing offsite wells. Monitoring either onsite or offsite would pose minimal risk to onsite workers, the public, or the environment.

4.4.2 Environmental and Public Health

This alternative, similar to onsite groundwater monitoring, would pose minimal or no short-term risk, but remedial action objectives would only by met through "natural" remediation measures (i.e., attenuation and dilution) and implementation of the Phase I ROD. However, until the Phase I treatment remediates shallow groundwater, contaminants will continue to leach and/or seep from the upper sand unit to the lower units. Therefore, the residual risk may increase before decreasing.

This alternative would involve no installation beyond that described for onsite monitoring. As with Alternative 2, no direct protection of human health or the environment is provided, except by providing information on chemical fate and transport.

This alternative also would be a direct and visible way of providing tangible assurance to the public that the quality of their drinking water is being monitored. The process of onsite and offsite monitoring by itself poses no threat to public health or the environment.

4.4.3 Compliance With ARAR's

This alternative would not meet ARAR's specified by the CWA and/or Safe Drinking Water Act onsite due to the documented exceedances of MCL's onsite. As with Alternative 2, applicable OSHA and air pollution regulations would be addressed in the remedial action plan.

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4.4.4 Cost

This alternative proposes the monitoring of 11 onsite wells and four offsite wells chosen to provide representative samples from the middle sand, lower sand, and bedrock units. Samples for wells would be taken on the same schedule as described in Section 3.3 and analyzed for the same constituents. Results would be submitted for review on the same schedule. The costs associated with onsite groundwater monitoring are the same as those outlined in the previous alternative (see Section 4.3.4, Table 4-1). The costs associated with offsite monitoring are detailed in Table 4-2. Costs are based on monitoring for a 30-year period.

This alternative would have a capital cost of approximately $79,900 and annual O&M costs of approximately $50,600. The net present worth of this alternative at a discount rate of 10 percent for 30 years is $549,900.

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TABLE 4-2
Cost Estimate for Onsite and Offsite Groundwater Monitoring
Alternative 3

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Construction Costs

Item	Rate ($)	Unit	Cost (1988 $)
• Onsite well installation subtotal (from Alternative 2)	—	—	55,600
CONSTRUCTION SUBTOTAL			55,600
CONSTRUCTION CONTINGENCIES (15%)			8,300
TOTAL CONSTRUCTION COST			63,900
DESIGN, ENGINEERING, AND CONSTRUCTION MANAGEMENT (25%)			16,000
TOTAL CAPITAL COST			79,900

Annual O&M Costs

Item	Rate ($)	Unit	Cost (1988 $)
• Onsite sampling subtotal (from Alternative 2)	—	—	36,000
• Onsite monitoring equipment subtotal (from Alternative 2, 5-year replacement)	—	—	600
• Offsite sampling costs - per sampling event			
Sample analyses - volatiles[a]	450/sample	6/event	2,700
Sample analyses - metals[a]	350/sample	1/year	400
Containers and shipping	85	4/event	300
Labor[b]	1,000/event	1 event	1,000
Equipment and equipment rental[c]	300/event	1 event	300
Report preparation and sampling management	400/event	1 event	400

TABLE 4-2 (cont'd)

Item	Rate ($)	Unit	Cost (1988 $)
Offsite Sampling Subtotal			5,100
• Offsite sampling equipment (5-year replacement)	125/well	4 wells	500
OPERATION AND MAINTENANCE SUBTOTAL			42,200
CONTINGENCY AND OVERHEAD (20%)			8,400
TOTAL ANNUAL O&M COST			50,600
NET PRESENT WORTH[d]			549,900

[a] CLP TCL volatiles and/or TAL metals.
[b] Includes per diem.
[c] Includes vehicle, generator, field supplies, etc.
[d] 30 years, 10%.

4.5 ALTERNATIVE 4--ONSITE AND OFFSITE GROUNDWATER MONITORING WITH DEFERRED OFFSITE TREATMENT

4.5.1 Technical Feasibility

The overall performance of this alternative would depend upon the compounds detected at the monitoring locations. VOC's are more likely to migrate downgradient than semivolatiles or metals. As described in Section 3.5, the point-of-use treatment units available would be activated carbon (organics), ion exchange (metals), and air stripping (hydrophobic organics). All units would serve singly or in series to remove compounds from drinking water.

Each unit operates with a different efficiency; in general, air strippers function best at high concentrations, because the stripping is based on concentration gradients. Only volatile organics would be removed. The GAC unit removes most organics and is most efficient when fresh carbon is used. As the carbon becomes saturated, efficiency decreases until chemical breakthrough eventually occurs. Ion exchange resins operate similar to GAC units, with the exception that they remove metals.

Treatability studies with these different units may be necessary to determine optimum O&M schedules and parameters. With proper installation, operation, and maintenance, these units should be able to achieve remedial objectives for the various compounds of concern and maintain a useful life of at least 30 years.

These units are extensively used in businesess and industry for a variety of water treatment needs. They have a significant record of demonstrated performance for hazardous and nonhazardous wastes. O&M requirements vary for all three systems, but maintenance can be scheduled to occur simultaneously.

Unit	Operational and Installation Requirements	Maintenance Requirements
Air Stripper	Booster pump at well head to raise water pressure. 110V electrical service with 15A fuse.	Blower and pump lubrication. Packing periodically checked for mineral deposition.

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Unit	Operational and Installation Requirements	Maintenance Requirements
	Fiberglass bladder pneumatic holding tank.	
	Filter if high particulate levels.	
	Iron removal if iron levels are above 6-7 ppm.	
GAC Unit	UV light system to deter bacterial growth.	Carbon change-out when saturation/breakthrough occurs.
		Backwash capability to prevent clogging by suspended solids.
Ion Exchange	None.	Cartridge replacement when saturation/breakthrough occurs.

Because the ion exchange and GAC systems are available as cartridge units, they may be connected in series or parallel for system flexibility and backup. The air stripping system must be adjusted to maintain an optimum air/water ratio based on flow and concentrations. The air stripping system would operate on a batch basis, and the GAC and ion exchange units are on demand.

Each unit could be installed and operational within an approximate 1-to-4-day period by an experienced plumber and, if necessary, electrician. The air stripping unit would require heat tracing and a small housing unit. The ion exchange and GAC system would fit either under the sink or in a basement.

Sampling and maintenance of these units will require access to the building utilizing the water (e.g., residential home). O&M requirements for these types of point-of-use systems are normally high, especially if a large number of systems are involved.

Saturated carbon and/or ion exchange resin would be removed on a scheduled basis by a subcontractor and transported to a regeneration facility. The installation and construction of the system is expected to cause minimal or no risks to public health or the environment.

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4.5.2 Environmental and Public Health

The environmental and public health aspects of onsite and offsite groundwater monitoring have been previously discussed in Sections 4.3.2 and 4.4.2. Only those additional impacts presented by offsite point-of-use treatment will be addressed here.

The installation of the point-of-use systems would pose a minor disruption in water service for the individual well being fitted. Installation would not pose any significant adverse health threat to the residents, community, or the environment. Water service should not be interrupted for more than a period of 4 to 10 hours, with complete system installation and calibration being accomplished in 1 to 4 days. Remedial objectives would be met at the point-of-use immediately (as soon as the system is operational).

All units would be removing compounds to a level at or below the remedial objectives (Section 1.4). All possible system controls would be automatic and would be checked during offsite monitoring events. Where feasible, two units in series would be used to provide a backup system in case of unexpected breakthrough.

The public health concerns associated with the use of activated carbon and ion exchange units principally include proper disposal of the saturated media and providing for prompt maintenance and troubleshooting expertise in the event that a unit would malfunction. After extended periods of operation, the unit could become enriched in adsorbable organics or metals from the groundwater being treated, and could represent a potential public health threat if the unit were not properly handled and disposed of or regenerated. Such potential health risks could be avoided by requiring appropriate documentation from the supplier of the unit to ensure that their servicing contract includes disposal or regeneration of the unit and the user follows operational instructions.

Although no unacceptable present risks to public health or the environment have been identified, the provision of monitoring and treatment on an as-needed basis would provide a measure of protection in the event of unforeseen circumstances. Should the offsite detections be due to an isolated pocket of analytes, this alternative would be protective of groundwater users in the area, without requiring the construction of a complete treatment system that may not necessarily be effective for long-term use.

Potential risks from the malfunction of a treatment unit and subsequent exposure of the groundwater users to untreated groundwater can be reduced to acceptable levels by providing residences with a telephone contact to request assistance if a malfunction is suspected, by providing effluent sampling to monitor for breakthrough, and by inspecting units during sampling.

4.5.3 Compliance With ARAR's

Regulatory aspects of onsite and offsite groundwater monitoring have been previously discussed in Section 4.2.3 and 4.3.3; only those compliances specific to point-of-use treatment will be addressed here.

This alternative would comply with MCL's (Safe Drinking Water Act) at the point-of-use. The regulations under the Clean Water Act are not applicable to point-of-use systems; therefore, an NPDES permit would not be required. OSHA requirements would be met by onsite and offsite workers during system installation and maintenance, and details of this compliance would be specified in the remedial action health and safety plan.

If used carbon and ion exchange canisters are determined to be hazardous, DOT regulations would be followed for transport to the regeneration facility, and proper manifesting would be required. Specific compliance with these regulations would be detailed in the remedial action plan.

4.5.4 Cost

Costs for this alternative would vary, depending upon the number and type of point-of-use treatment units installed. A range of costs has been developed based on best-case (no treatment units necessary) and worst-case (all three treatment technologies required for all residences and businesses within the affected area within the first year) situations. It is important to note that costs presented are order-of-magnitude estimates and are to be used for comparison purposes only. Actual costs may differ due to development in the area or a larger population affected. The costs associated with this alternative are detailed in Table 4-3. The costs for the best-case situation would be the same as those developed for the onsite and offsite groundwater monitoring alternative (capital = $79,900, O&M = $50,600 annually, and net present worth = $549,900).

The worst-case estimate is based on a maximum of 25 residences and three businesses requiring installation of point-of-use water treatment systems

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(determined from projected growth rates for the area). Costs for the treatment systems were based on vendor quotes for installed units (Culligan, 1988); where applicable, unit costs are given. Costs for carbon adsorption units include two 1½-ft^3 units, three sampling ports, a water meter, and an ultraviolet light system. Sampling is assumed to occur in conjunction with monitoring. The number of residences/businesses and/or monitoring wells sampled is assumed to remain constant over time. Realistically, this number may increase at any time should migration occur. This case would have a capital cost of $516,100, O&M costs of $114,600 per year, and a net present worth (30 years, 10 percent) of $1,589,700. *Monitoring for all units would continue on an annual basis for 30 years.* As with previous alternatives, the scope and schedule for monitoring would be reevaluated, at a minimum, every 5 years.

TABLE 4-3
Worst-case Cost Estimate for Onsite and Offsite
Groundwater Monitoring with Deferred Offsite Treatment
Alternative 4

Construction Costs

Item	Rate ($)	Unit	Cost (1988 $)
• Onsite well installation subtotal (from Alternative 2)	—	—	55,600
• Carbon adsorption units[a]			
Single-family home units	1,700/unit	25 units	42,500
Business units	3,900/unit	3 units	11,700
Carbon Adsorption Subtotal			54,200
• Ion exchange units[b]			
Single-family home units	2,700/unit	25 units	67,500
Business units	4,800/unit	3 units	14,400
Ion Exchange Subtotal			81,900
• Air stripping units[b]			
All units	3,920/unit	28 units	109,800
Manganese/green sand filter for iron removal	1,100/unit	28 units	30,800
Pneumatic bladder tank - home	225/unit	25 units	5,600
business	725/unit	3 units	2,200
Concrete pad	150/unit	28 units	4,200
Housing and heat	525/unit	28 units	14,700

TABLE 4-3 (cont'd)

Item	Rate ($)	Unit	Cost (1988 $)
Air Stripper Subtotal			167,300
CONSTRUCTION SUBTOTAL			359,000
CONSTRUCTION CONTINGENCY (15%)			53,900
TOTAL CONSTRUCTION COST			412,900
DESIGN, ENGINEERING, AND CONSTRUCTION MANAGEMENT (25%)			103,200
TOTAL CAPITAL COST			516,100
Annual O&M Costs			
• Onsite sampling subtotal (from Alternative 2)	—	—	36,000
• Onsite sampling equipment subtotal (from Alternative 2, 5-year replacement)	—	—	600
• Offsite sampling subtotal (from Alternative 3)	—	—	5,100
• Offsite sampling equipment subtotal (from Alternative 3)	—	—	500
• Carbon adsorption units[d]			
Replace carbon and disposal of used cartridges[d]	350/cart.	28 cart.	9,800
UV lamps	90/unit	28 units	2,500
Carbon Adsorption Subtotal			12,300
• Ion Exchange Units[d]			
Replacement resin cartridges[c]	110/cart.	28 cart.	3,100

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TABLE 4-3 (cont'd)

Item	Rate ($)	Unit	Cost (1988 $)
Ion Exchange Subtotal			3,100
• Air stripping units			
Electricity - home[e]	0.07/kw-hr	2,200 kw-hr/unit	3,900
Electricity - business[f]	0.07/kw-hr	6,600 kw-hr/unit	1,400
Blower and motor maintenance and inspection	100/unit	28 units	2,800
Air Stripping Subtotal			8,100
• Sampling for all units[g]			
Sample analyses[h]	800/sample	32/event	25,600
Containers and shipping	1,360/event	1 event	1,400
Labor[i]	2,000/event	1 event	2,000
Equipment and equipment rental[j]	200/event	1 event	200
Report preparation and sampling management	600/year	1 year	600
Unit Sampling Subtotal			29,800

TABLE 4-3 (cont'd)

Item	Rate ($)	Unit	Cost (1988 $)
OPERATION AND MAINTENANCE SUBTOTAL			95,500
CONTINGENCY AND OVERHEAD (20%)			19,100
TOTAL ANNUAL O&M COST			114,600
NET PRESENT WORTH[k]			1,589,700

[a] Includes UV disinfection unit and system installation.
[b] Installed.
[c] Includes labor.
[d] Assumes 1 cartridge per year replacement.
[e] Assuming 1/2 hp pumps in residential wells in operation 8 hours/day.
[f] Assuming 1/2 hp pumps in wells operational 24 hrs/day.
[g] Assumed to be done in conjunction with groundwater monitoring.
[h] CLP TCL volatiles and TAL metals.
[i] Includes per diem.
[j] Includes vehicle, generator, field supplies, etc.
[k] 30 years, 10%.

4.6 ALTERNATIVE 5--ONSITE GROUNDWATER MONITORING WITH DEFERRED ONSITE TREATMENT

4.6.1 Technical Feasibility

The technical feasibility aspects of onsite groundwater monitoring have been previously discussed in Section 4.3.1. In addition, the technical feasibility of the Phase I treatment system is detailed in the Phase I FS (Section 10.7). This section will discuss the impacts of groundwater extraction and the scale-up of the Phase I system.

The groundwater treatment portion of this alternative may have negative impacts on the groundwater quality within the confined units if it is implemented before the contaminant sources affecting the perched water table aquifer, sediments, and soils at the EEA are removed or controlled. Lowering of the hydraulic head by pumping from the middle sand unit may accelerate the rate of downward migration/infiltration of contaminated near-surface groundwater.

The extent to which groundwater pumping could cause contaminant migration from the upper sand unit at the EEA, causing additional contamination of the underlying units, depends somewhat on the continuity and low hydraulic conductivity of the upper confining clay that separates the upper sand unit from the underlying units. Well-defined groundwater seeps at the surface where the upper confining clay crops out and the logs of borings from the EEA suggest that the upper confining clay probably forms an effective barrier, and direct leakage downward through this confining clay may not be the dominant pathway for induced leachate migration.

The most likely pathway for induced leachate migration is from the areas of the groundwater seeps (Sedge Meadow Area, area between pond P01 and the swamp, and the area east of pond P02). Lowering of the hydraulic head within the middle sand unit at these locations may encourage infiltration of contaminated seepage (discharging from the upper sand unit) directly into the middle sand unit, which is unconfined in the vicinity of these seeps.

The likelihood of this seepage occurring could be minimized by utilizing infiltration trenches or basins. These can be sited to encourage groundwater movement back toward the extraction wells, thus flushing out contaminants from the aquifer. In addition, this selective discharge to certain areas may produce a hydraulic barrier tending to limit migration away from the EEA.

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If the rate of induced contaminant influx exceeds the rate of contaminant removal by groundwater treatment and other natural attenuative mechanisms, then net groundwater quality will deteriorate. Contaminant removal rates from the confined/semiconfined water-bearing units at MSGS due to groundwater pumping/ treatment are estimated to be low because of the poor water-producing capacity (low transmissivity) of these units. Simultaneously, the reduction of hydraulic heads in response to pumping is estimated to be high because of the low transmissivities. This combination of a low rate of contaminated groundwater removal and high potential for head reduction indicates that groundwater pumping and treatment from the middle sand unit may induce the spread of contamination if it is implemented before the leachate source in the upper sand unit at the EEA is controlled or limited.

Pumping and treatment of groundwater from the confined and semiconfined units of MSGS should only be considered for implementation after the potential contaminant sources within upper and middle sand unit groundwater, soils, and sediments at the EEA have been eliminated or controlled (i.e., remedies have been successfully implemented) and if the onsite groundwater monitoring shows an increase in analyte concentrations in the deeper water-bearing units, despite implementation of the Phase I groundwater treatment system.

The three-well groundwater extraction system would produce approximately a 10-foot drawdown. This drawdown would reverse the localized groundwater flow gradient, causing groundwater to flow back towards the extraction wells. The extraction system, in conjunction with a properly designed Phase I treatment system, would be effective in permanently reducing the toxicity, while decreasing the mobility and volume of analytes in the middle sand unit. Effluent concentrations would meet all remedial objectives and discharge requirements.

Groundwater extraction systems are very similar to monitoring systems in terms of operation and maintenance requirements. These systems are mechanically quite simple and, therefore, reliable. They are extensively used in hazardous and nonhazardous groundwater management systems. The major potential operational failures would be related to (1) insufficient groundwater recharge into the well causing low flow conditions, (2) failure of in-well low-level sensors causing pump burnout, and (3) failure (frequently due to lightning) of the electrical system and (4) vandalism. The recharge difficulties may be addressed by relocating the well, making the well deeper, or adding an additional well to the system to supplement flow. Electrical and pump failures would best be addressed by frequent inspections or a remote sensing device.

The Phase I system should have the capacity to accommodate changes in flow and will not be adversely affected by the loss of flow from a well. The extraction wells have an estimated useful life of 30 years (the life of the system). With proper O&M, this could be extended, if necessary. The groundwater extraction piping system is susceptible to freezing and must be constructed below the frost line to prevent ice buildup and clogging.

Groundwater extraction wells will require essentially the same installation procedures as those described for onsite monitoring wells. Installation of the associated piping back to the Phase I system would require excavation equipment and health and safety trained personnel, but should not be difficult or time-consuming. Installation of the groundwater extraction wells would pose essentially the same hazards as described for onsite monitoring well installation. Trenching for piping may produce significant dust and noise. If done after Phase I source removal, exposure to compounds from soil contact should be minimal.

The scale-up of the Phase I system to accommodate the increase in flow should not affect the overall technical feasibility of the system. The flow increase would be approximately 10 gpm or 14,400 gpd. The Phase I FS does not appear to state the rated capacity of the plant, but the filters are sized for 15 gpm. Based on this, the system will be essentially doubled in capacity.

4.6.2 Environmental and Public Health

Only those environmental and public health impacts caused by groundwater extraction will be addressed in this section. The impacts of onsite groundwater monitoring were discussed in Section 4.3.2.

The installation of the groundwater extraction wells and all ancillary piping would be likely to produce short-term, temporary increases in noise and dust levels. Monitoring may be required to determine if dust or noise levels are elevated significantly enough to warrant special controls. Onsite monitoring would most likely be necessary for the protection of onsite workers. All worker protection measures would be described in detail in the remedial action health and safety plan.

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The time until remedial action objectives are achieved cannot be determined with any accuracy. Even extensive groundwater models are based on many assumptions and approximations, and are usually considered order-of-magnitude accurate. Therefore, the residual risk upon completion of treatment cannot be determined. This alternative would pose minimal or no risks to public health or the environment during installation or operation.

This alternative would be protective of public health and the environment by permanently reducing the onsite volume, toxicity, and mobility of compounds found in the middle sand unit. Groundwater migration offsite would be minimized through the use of a groundwater extraction system, thereby reducing the threat of degradation of offsite drinking water wells. However, until the Phase I system succeeds in remediating the upper sand unit, contaminants will continue to leach and/or seep into the lower units, and possibly migrate offsite. Therefore, the residual risk may increase with time, before decrease is observed.

4.6.3 Compliance With ARAR's

Compliance issues for onsite groundwater monitoring have been previously discussed in Section 4.3.3. This alternative would meet or exceed all potential ARAR's identified in Section 4.1.3, either by virtue of the onsite treatment system (CWA and Safe Drinking Water Act) or via engineering controls (NPDES and Clean Air Act). Compliance with select ARAR's would be specified in detail in the work plan for the remedial action (OSHA and DOT). The FS and/or work plan would be reviewed in detail by all affected agencies to verify compliance with these regulations.

The question of wetlands onsite has been addressed in the Bioassessment Report (CDR, 1988). This assessment would be reviewed along with the work plan by the appropriate agencies.

4.6.4 Cost

Costs for the first phase of this alternative would be identical to those developed for Alternative 2--onsite groundwater monitoring. This monitoring would have a capital cost of $79,900, an annual O&M of $43,900, and a net present worth (30 years at 10 percent) of $464,100. The costs associated with this alternative are detailed in Table 4-4.

Costs for treatment were based on the change in flow capacity that would be required by the Phase I treatment system to accomodate groundwater extracted from the middle sand unit. The Phase I system would require approximately twice the current design capacity. The cost of this increase has been estimated as 50 percent of the capital and O&M costs presented in the Phase I FS. This may provide an overly high estimate, because doubling the size of many operational units (e.g., filters) does not necessarily double the price. The majority of the net present worth costs stem from the high O&M costs of the Phase I system. The Phase I FS states that the useful life of the system is 5 years; therefore, the annual O&M for the system was assumed to be incurred for only the first 5 years. The total worst-case cost of this alternative, assuming both onsite monitoring and treatment, would involve a capital cost of $1,116,300, an annual O&M of $495,700, and a net present worth of $3,212,700.

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TABLE 4-4
Cost Estimate for Onsite Groundwater
Monitoring with Deferred Onsite (Phase I) Treatment
Alternative 5

Construction Costs

Item	Rate ($)	Unit	Cost (1988 $)
• Onsite well installation subtotal (from Alternative 2)	—	—	55,600
• Extraction well installation (EW-1, EW-2, EW-3)[a]			
Drilling 12" hole for steel surface casing (EW-1)	24/ft	32 ft	800
8" steel surface casing, installed and grouted (EW-1)	42/ft	30 ft	1,300
Flushing surface casing	165/hr	2.5 hr/well	400
Drilling 8" hole	18/ft	160 ft	2,900
Installation of 6" well[b]	24/ft	196 ft	4,700
Filling borehole below well tip	165/hr	4 hrs	700
Well covers, steel, locking	300 each	3 covers	900
Drums for drill fluid	65/dr	40 dr/well	7,800
Fill drums	165/hr	2 hr/well	1,300
Decontamination of equipment	165/hr	6 hr/well	4,000
Well development	120/hr	5.5 hr/well	2,600
Standby	165/hr	2 hr/well	1,300
Disposal of drilling fluids[c]	65/drum	40 dr/well	7,800
Transportation of drilling fluids for offsite disposal[c]	500/load	2 loads	1,000
Sampling and analysis of drilling fluid[d]	1005/sample	2/well	6,000
Well surveying	200/well	3 wells	600
Extraction Well Subtotal			44,100
• Utilization of Phase I system			
Piping, 4" PVC	14.50/LF	3500 LF	50,800
Trench excavation and backfill (12" x 36")	1.50/LF	3500 LF	5,300
Plumbing and connections	—	—	600

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TABLE 4-4 (cont'd)

Item	Rate ($)	Unit	Cost (1988 $)
Pumps	300 each	3 pumps	900
Stone rip-rap	$25/yd^3$	$100\ yd^3$	2,500
Fifty percent increase in Phase I System capital cost (Phase I FS)	—	—	616,700
Utilization of Phase I System Subtotal			676,800
CONSTRUCTION SUBTOTAL			776,500
CONSTRUCTION CONTINGENCIES (15%)			116,500
TOTAL CONSTRUCTION COST			893,000
DESIGN, ENGINEERING, AND CONSTRUCTION MANAGEMENT (25%)			223,300
TOTAL CAPITAL COST			1,116,300
Annual O&M Costs			
• Onsite sampling subtotal (from Alternative 2)	—	—	36,000
• Onsite sampling equipment (from Alternative 2, 5-year replacement)	—	—	600
• 50 percent of Phase I System O&M (Phase I FS, 5-year duration)	—	—	376,500

TABLE 4-4 (cont'd)

Item	Rate ($)	Unit	Cost (1988 $)
OPERATION AND MAINTENANCE SUBTOTAL			413,100
CONTINGENCY AND OVERHEAD (20%)			82,600
TOTAL ANNUAL O&M COST			495,700
NET PRESENT WORTH[e]			3,212,700

[a] Assuming installation is concurrent with monitoring well installation. If not, an additional $500 mobilization/demobilization fee would apply.
[b] Includes installation of well, screen, sand pack, bentonite, and grout to surface.
[c] Waste Conversion, Inc., 1988.
[d] CLP TCL volatiles, semivolatiles, and TAL metals.
[e] 30 years, 10%.

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4.7 ALTERNATIVE 6--ONSITE AND OFFSITE GROUNDWATER MONITORING WITH DEFERRED ONSITE AND OFFSITE TREATMENT

4.7.1 Technical Feasibility

The technical aspects of the monitoring and treatment components of this alternative have been discussed for previous alternatives. As described in Sections 4.3.1 and 4.4.1, monitoring of onsite and offsite wells should have relatively high implementability, reliability, useful lives, and low O&M costs. Implementation of onsite treatment would use a scale-up of the Phase I system; technical aspects of expanding the Phase I treatment system are described in Section 4.6.1. Technical aspects of implementing offsite treatment are discussed in Section 4.5.1. There would appear to be no technical impediments to implementing both onsite and offsite treatment (if necessary), as opposed to implementing either onsite or offsite treatment individually.

4.7.2 Environmental and Public Health

Implementation of onsite treatment, if so indicated by monitoring data, would be protective of public health and the environment by permanently reducing the onsite volume, toxicity, and mobility of compounds found in the middle sand unit. Installation of point-of-use treatment systems (if necessary) would be protective of public health because remedial objectives would be met at the point-of-use immediately, as soon as the system is operational. Additional discussions of health aspects of onsite and offsite treatment are provided in Sections 4.6.2 and 4.5.2, respectively.

4.7.3 Compliance With ARAR's

Regulatory aspects of onsite and offsite groundwater monitoring were discussed in Sections 4.2.3 and 4.3.3. Treatment of onsite groundwater was reviewed for compliance with ARAR's in Section 4.6.3; the equivalent section for offsite treatment is 4.5.3. This alternative would meet or exceed all potentially applicable ARAR's identified in Section 4.1.3.

4.7.4 Cost

Costs for this alternative would vary, depending on whether onsite treatment, offsite treatment, or both are found to be necessary. Offsite treatment costs would also vary with the number and type of treatment units installed. A range of

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costs has been developed based on best-case (no treatment units necessary) and three worst-case (onsite treatment, offsite treatment, or both) situations. The costs associated with this alternative are detailed in Table 4-5.

The costs for the best-case situation would be the same as those developed for the onsite and offsite groundwater monitoring alternative (Alternative 3) (capital = $79,900, O&M = $50,600 annually, and net present worth = $549,900).

Implementation of offsite treatment on a worst-case basis is based on a maximum of 25 residences and three businesses requiring installation of water treatment systems. Offsite treatment would require additional capital costs of $435,400 and annual O&M costs of $64,000 for 30 years. Total costs for this case would be the same as for Alternative 4--a total capital cost of $516,100, O&M costs of $114,600 per year, and a net present worth of $1,589,700.

Costs for onsite treatment (if necessary) have been estimated on a scale-up of the Phase I treatment system, as described in Section 4.6.4. Additional costs for onsite treatment would include capital costs of $1,036,300 and annual O&M costs of $451,800. Total costs for this case would be--a total capital cost of $1,551,500, an annual O&M of $671,300, and a net present worth of $4,337,400.

A final worst-case would be if both onsite and offsite treatment were found to be necessary. Costs for this case would be as follows:

	Capital Costs	Annual O&M
Onsite and Offsite Groundwater Monitoring	$ 79,900	$ 50,600
Offsite Treatment for 25 Residences and Three Businesses	$ 435,400	$ 64,000
Onsite Treatment Using the Phase I System	$1,036,300	$451,800

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TABLE 4-5
Cost Estimate for Onsite and Offsite Groundwater
Monitoring with Deferred Onsite (Phase I) and Offsite Treatment
Alternative 6

Construction Costs

Item	Rate ($)	Unit	Cost (1988 $)
• Onsite well installation subtotal (from Alternative 2)	—	—	55,600
Onsite Monitoring Subtotal			55,600
• Onsite Treatment			
Extraction well subtotal (from Alternative 5)	—	—	44,100
Utilization of Phase I system subtotal (from Alternative 5)	—	—	676,800
Onsite Treatment Subtotal			720,900
• Offsite Treatment (from Alternative 4)			
Carbon adsorption subtotal	—	—	54,200
Ion exchange subtotal	—	—	81,900
Air stripper subtotal	—	—	166,700
Offsite Treatment Subtotal			302,800
CONSTRUCTION SUBTOTAL			1,079,300
CONSTRUCTION CONTINGENCIES (15%)			161,900
TOTAL CONSTRUCTION COST			1,241,200
DESIGN, ENGINEERING, AND CONSTRUCTION MANAGEMENT (25%)			310,300
TOTAL CAPITAL COST			1,551,500

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TABLE 4-5 (cont'd)

Item	Rate ($)	Unit	Cost (1988 $)
Annual O&M Costs			
• Monitoring			
Onsite sampling subtotal (from Alternative 2)	—	—	36,000
Onsite sampling equipment (from Alternative 2, 5-year replacement)	—	—	600
Offsite sampling subtotal (from Alternative 3)	—	—	5,100
Offsite sampling equipment (from Alternative 3)	—	—	500
Monitoring Subtotal			42,200
• Onsite Treatment			
50 percent of Phase I System O&M (Phase I FS, 5-year duration)	—	—	376,500
Onsite Treatment Subtotal			376,500
• Offsite Treatment (from Alternative 4)			
Carbon adsorption subtotal	—	—	12,300
Ion exchange subtotal	—	—	3,100
Air stripping subtotal	—	—	8,100
Unit sampling subtotal	—	—	117,200
Offsite Treatment Subtotal			140,700

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TABLE 4-5 (cont'd)

Item	Rate ($)	Unit	Cost (1988 $)
OPERATION AND MAINTENANCE SUBTOTAL			559,400
CONTINGENCY AND OVERHEAD (20%)			111,900
TOTAL ANNUAL O&M COST			671,300
NET PRESENT WORTH[a]			4,337,400

[a] 30 years, 10%.

4.8 SENSITIVITY ANALYSIS

Table 4-6 shows the effect of a variable discount rate on overall site alternative costs. The effect of a variable discount rate would exert the greatest effect on alternatives having higher O&M costs, as would be expected. The fourth through sixth alternatives would have the highest proportion of O&M costs; consequently, they would be the most affected by a variation in the discount rate.

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TABLE 4-6

Sensitivity Analysis--Variation of Costs with Discount Rate

Alternative	Original Estimate[a]	Discount Rate 5%	Discount Rate 20%
1--No Action	0	0	0
2--Onsite Groundwater Monitoring	464	746	296
3--Onsite and Offsite Groundwater Monitoring	550	842	327
4--Onsite and Offsite Groundwater Monitoring with Deferred Offsite Treatment (worst case)	1,590	2,260	1,081
5--Onsite Groundwater Monitoring with Deferred Onsite Treatment (Phase I System) (worst case)	3,213	3,738	2,682
6--Onsite and Offsite Groundwater Monitoring with Deferred Onsite and Offsite Treatment (worst case)	4,338	5,251	3,466

[a]Total program costs in thousands of dollars, net present worth in 1988 dollars, 10% discount rate for 30 years.

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5.0 RECOMMENDED REMEDIAL ALTERNATIVE

The detailed analysis of the remedial action alternatives in Section 4.0 is summarized in Table 5-1. This overview allows the six alternatives to be compared with regard to technical feasibility and implementability; protection of public health and the environment; long- and short-term effectiveness, permanence, and overall protection; ability to meet remedial objectives; compliance with ARAR's; and cost considerations. Based on the results of the Section 4.0 analysis, Alternative 6--onsite and offsite groundwater monitoring with (if indicated by monitoring) onsite treatment using the Phase I system and (if indicated by monitoring) offsite point-of-use treatment consisting of carbon adsorption, ion exchange, and/or air stripping--is the recommended Phase II remedial alternative for the MSGS site. The existence of contamination in the middle sand unit has only been indicated from one monitoring well. Additional wells (discussed in Alternative 2--MS-1, MS-2, MS-3, and LS-1) should be installed to determine the extent of contamination in the middle sand unit before a remediation plan is formulated. If no contamination is found, only monitoring of the middle sand unit would be implemented.

The groundwater treatment portion of this alternative may have negative impacts on the groundwater quality within the confined units if it is implemented before the contaminant sources affecting the upper sand unit, sediments, and soils at the EEA are removed or controlled (i.e., remedies have been successfully implemented). Therefore, pumping and treatment of the middle sand unit will not be considered until after the potential contaminant sources within upper sand unit groundwater, soils, and sediments at the EEA have been controlled or eliminated and until the onsite groundwater monitoring shows an increase in analyte concentrations in the deeper water-bearing units, despite implementation of the Phase I ROD. Although onsite development is not anticipated during the period of possible onsite treatment, water use controls to prohibit the onsite use of groundwater should be considered during final system design.

After review of the major screening factors used for each alternative, it is evident that this remedial action has:

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- Technical feasibility and implementability, using established practices.
- Overall protection of public health and the environment.
- Compliance with potentially applicable ARAR's.
- Long-term effectiveness and permanence, as well as short-term effectiveness.
- Overall reduction of the toxicity, mobility, and volume of contamination.
- Acceptable levels of capital and O&M costs.

This alternative attains or exceeds ARAR-based remedial objectives at the site and is protective of human health and the environment, while giving all parties maximum flexibility to adapt the remedial program to conditions at and near the site over time. The alternative is supportive of a permanent solution to the maximum extent practicable, assuming that the Phase I remedy will be as effective as anticipated.

This alternative is recommended over groundwater monitoring with deferred offsite point-of-use treatment because of the additional level of assurance provided to offsite water users. In conclusion, onsite and offsite groundwater monitoring with onsite treatment (as necessary) utilizing the Phase I ROD system and offsite treatment (as necessary) using point-of-use treatment (carbon adsorption, ion exchange, and/or air stripping) meet the statutory requirements for a selected remedy and are appropriate Phase II remedial actions for the MSGS site.

Table 5-1
Summary Table of Remedial Alternatives
Narrative Matrix

Alternative	Implementability	Impacts on Effectiveness, Public Health and the Environment	Compliance with ARARs	Cost (thousands of dollars) Capital	O&M	NPV(a)
1-No Action	Not Applicable	No remediation. Risks presented in EA will be lowered only by Phase I ROD actions and/or natural mechanisms.	Clean Water Act and/or Safe Drinking Water Act MCL restrictions are violated onsite.	0	0	0
2-Onsite Groundwater Monitoring	Reliable, low O&M requirements. Low/no health risks during installation. No reduction of toxicity, mobility or volume of compounds as a direct result of implementation. Useful life equals 30 years. Short term increases in noise and dust.	Minimal/no short-term risk to public health/environment. Risk from future groundwater use still exists. Remedial objectives not achieved via remediation.	Clean Water Act and/or Safe Drinking Water Act MCL restrictions are violated onsite. Clean Air Act and OSHA Regulations would be met via workplan specifications.	80	44	464
3-Onsite and Offsite Groundwater Monitoring	Reliable, low O&M requirements. Low/no health risks during installation. No reduction of toxicity, mobility or volume of compounds as a direct result of implementation. Useful life equals 30 years. Short term increases in noise and dust.	Minimal/no short-term risk to public health/environment. Risk from future groundwater use still exists. Remedial objectives not achieved via remediation.	Clean Water Act and/or Safe Drinking Water Act MCL restrictions are violated onsite. Clean Air Act and OSHA Regulations would be met via workplan specifications.	80	51	550
4-Onsite and Offsite Groundwater Monitoring with Deferred Offsite Point-of-Use Treatment	Treatability studies required. Useful life of 30 years. Operationally simple and reliable. Rapid installation. Immediately operable.	Minimal/no short-term risks during installation. Proper O&M necessary to maintain effectiveness. Used resin and/or carbon may be hazardous.	Would meet MCL's at point-of-use. OSHA, Clean Air Act and DOT regulations would be met via work plan specifications.	80(d) 516(e)	51(d) 115(e)	550(d) 1,590(e)
5-Onsite Groundwater Monitoring with Deferred Onsite Groundwater Treatment (Phase I System)	Impacts of Phase I system evaluated in Phase I FS. Useful life of 30 years	Short-term, temporary increases in noise and dust levels. Minimal/no risks to public health/environment during installation or operation. Impacts of Phase I system evaluated in Phase I FS. Risk of undetected offsite groundwater degradation and subsequent use still exists.	Meets or exceed all potential ARARs onsite OSHA and DOT regulations addressed in work plan.	80(b) 1,116(c)	44(b) 496(c)	464(b) 3,213(c)
6-Onsite and Offsite Groundwater Monitoring with Deferred Offsite and Onsite Treatment	Impacts of Phase I system evaluated in Phase I FS. Useful life of 30 years	Short-term, temporary increases in noise and dust levels. Minimal/no risks to public health/environment during installation or operation. Impacts of Phase I system evaluated in Phase I FS.	Meets or exceed all potential ARARs onsite OSHA and DOT regulations addressed in work plan.	80(b)(d) 516(b)(e) 1,116(c)(d) 1,552(c)(e)	51(b)(d) 115(b)(e) 501(c)(d) 671(c)(e)	550(b)(d) 1,590(b)(e) 3,2[illegible](c)(d) 4,337(c)(e)

Key: (a) Net present worth; evaluated at a 10% discount rate for 30 years.
(b) If onsite treatment is not necessary.
(c) If onsite treatment is necessary.
(d) If offsite treatment is not necessary.
(e) If offsite treatment is necessary.

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APPENDIX

APPENDIX A

SIMULATION OF DRAWDOWN RESULTING FROM OPERATION OF EXTRACTION WELLS

A.1 SELECTION OF SIMULATION METHOD

For the purposes of this report, it was necessary to estimate the drawdown in the middle sand unit that might result from the combined pumping of three proposed extraction wells. Although drawdown from a single well can be calculated conveniently using analytical or graphical methods, manually combining the effects of three wells at a large number of points in order to construct a map showing drawdown throughout an area would be very tedious. Consequently, a digital groundwater model, MODFLOW, was selected.

The model had the additional advantage that water level in the pumping well could be fixed, and resulting drawdown elsewhere in the aquifer then calculated. Analytical models of pumping from wells would require assuming a pumping rate, and finding the pumping rate that would produce a reasonable drawdown by trial and error. In practice, pumping systems in extraction wells would probably be designed to maintain a constant drawdown level, rather than a constant pumping rate.

It should be noted that MODFLOW was selected as a matter of convenience, and not because the detail or accuracy of available data suggested use of a model capable of highly detailed simulations. In fact, this simulation was made only for preliminary design purposes, and is relatively simplified.

A.2 THE MODFLOW PROGRAM

MODFLOW is a digital computer model of three-dimensional ground-water flow. This model was developed by McDonald and Harbaugh (1984), and is the latest of a family of finite-difference flow models developed by the U.S. Geological Survey. The model is widely used, and is considered reliable.

The model depends on simulating the volume of aquifer being considered as a set of rectangular cells. In three dimensions, these cells are like rectangular boxes stacked together to completely fill a rectangular volume. The present simulation used only a single layer of cells, representing a part of the middle sand unit, and is thus a two-dimensional simulation. Flow between cells and associated changes in hydraulic head (equivalent to water level in wells) are simulated on the basis of Darcy's Law and the storage characteristics of the aquifer material.

For this simulation, principal model inputs consisted of aquifer hydraulic conductivity; recharge rate; hydraulic conditions at model boundaries; and location of, and head at, constant-head cells representing wells pumping at a constant water level. Principal model output consists of a table showing drawdown at the various cells.

A.3 MODEL GRID AND INPUT VALUES

The first step in preparing the model input data was selection of a model grid, or rectangular array of cells defining the model area. The grid is shown in Figure A-1. It consists of a 32 by 32 array of square cells, with each cell side 135.14 feet long. The area simulated was chosen to cover the area where there is information from the middle sand unit, and was also chosen large enough that drawdown effects from the pumping would be negligible near the boundaries so that boundary effects would not greatly affect simulated drawdown near the wells.

Transmissivity was estimated to be 1.15 ft^2/day, on the basis of an assumed aquifer saturated thickness of 20 feet (based on cross sections and reported water levels) and one measurement of hydraulic conductivity, 5.73E-2 ft/day, reported in Table 5-6 of the Phase II Remedial Investigation Report. Because the transmissivity value is based on only a single value of hydraulic conductivity, its reliability is considered relatively low. Change in transmissivity resulting from drawdown was not simulated, but transmissivity was assumed constant.

The simulation was steady-state, that is, it represents the situation after pumping had continued long enough that water levels had stabilized everywhere within the model area. A storage coefficient is not used in a steady-state simulation.

The recharge rate to the middle sand unit was initially assumed to be 4 inches/year, approximately half the recharge rate at the land surface. The first simulation runs using this recharge rate produced extremely large and obviously unreasonable increases in groundwater level. It was concluded that the recharge rate was very small, and a value of zero was used as a first approximation; that is, the aquifer was assumed to be confined.

The starting head was assumed to be 80 feet everywhere within the model area, including cells along the outer boundary, which were defined as constant-head. Head at these cells was not allowed to change during the simulation; they therefore represented an area far enough from the wells to be unaffected by extraction pumping. Note that because the head was assumed the same everywhere along the boundary, the slope of the potentiometric surface in the middle sand (which is not known accurately) is ignored as a first approximation.

Pumping wells were simulated as cells with constant heads of 70 feet, thus representing a constant 10 feet of drawdown.

A.4 MODEL RESULTS

Output from the model is reproduced as Attachment A-1. The output is annotated to show significant features, such as locations of wells.

Pumping rates from wells were calculated using Darcy's Law applied between well cells and the four adjacent cells. Heads in the well cell and surrounding cells were obtained from the output, and flow across each of the four boundaries of the well cell was calculated by multiplying the length of the cell boundary, the aquifer transmissivity, and the head gradient, or difference in head across the boundary divided by the distance between the centers of the cells. Calculations are presented in Table A-1. The simulated pumping rates are very small, totalling less than 1 gpm for all three wells. This small rate is considered suspect, based on experience with wells at the site. The more conservative pumping rate of 10 gpm was assumed in the report in discussing treatment of middle sand unit groundwater using the Phase I treatment system.

REFERENCE

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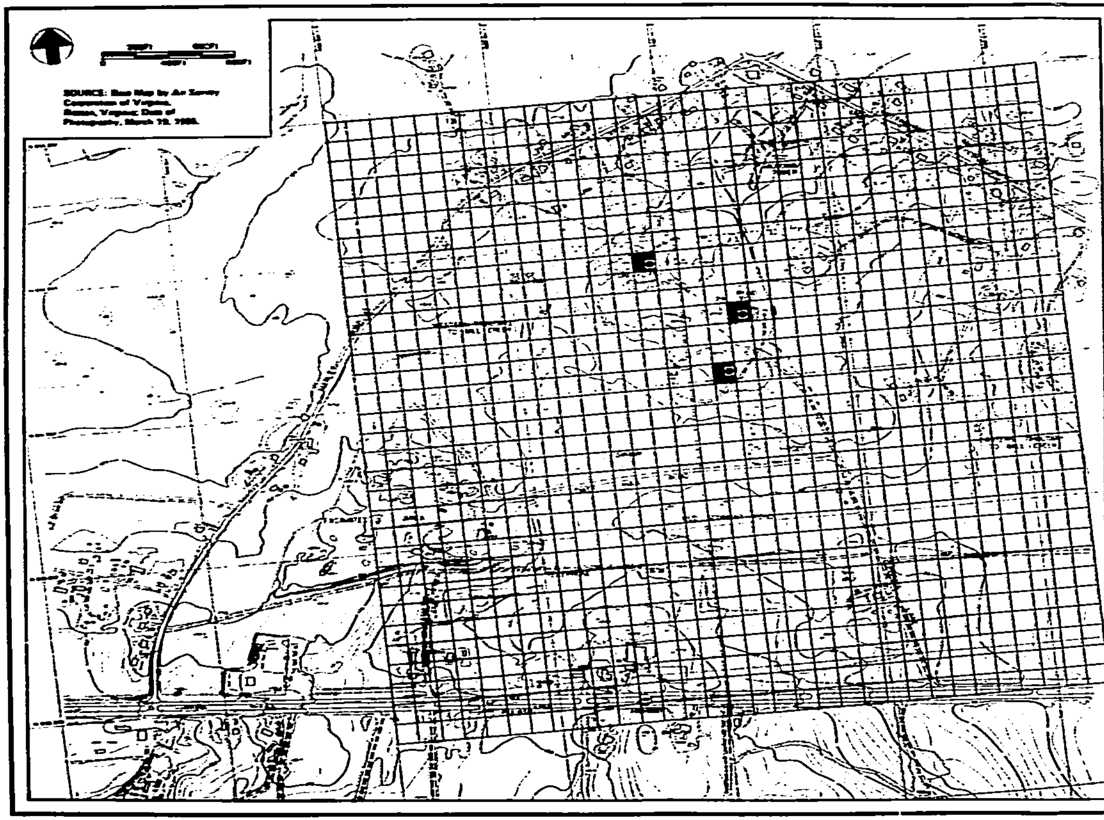
TABLE A-1
COMPUTATION OF DISCHARGE TO EXTRACTION WELLS

Flow rates to MSGS wells
Drawdown at wells=10ft

DRAWDOWN	dh	dh/dl	TxL	Q (ft3/d)	Q (GPM)	Q Total, by well (gpm)
6.8	3.2	0.023679	155.411	3.68	0.019115	
7.0	3	0.022199	155.411	3.45	0.017920	
7.5	2.5	0.018499	155.411	2.875	0.014934	
7.7	2.3	0.017019	155.411	2.645	0.013739	
						0.065709
7.6	2.4	0.017759	155.411	2.76	0.014336	
8.3	1.7	0.012579	155.411	1.955	0.010155	
7.5	2.5	0.018499	155.411	2.875	0.014934	
8.3	1.7	0.012579	155.411	1.955	0.010155	
						0.049580
8.4	1.6	0.011839	155.411	1.84	0.009557	
7.7	2.3	0.017019	155.411	2.645	0.013739	
7.7	2.3	0.017019	155.411	2.645	0.013739	
7.3	2.7	0.019979	155.411	3.105	0.016128	
						0.053165

GRAND TOTAL (gpm)=0.168455

NOTES:
- Drawdown = Drawdown at cells adjacent to pumping well cell (feet)
- dh = Head difference between well and adjacent cell (feet)
- dl = distance between cell centers (feet)
- dh/dl = Head gradient
- T = Transmissivity (sq ft/day)
- L = Length of side of cell (feet)
- Q = Well discharge



KEY:
Extraction Well

305 7

FIGURE A-1
MODEL GRID FOR
MIDDLE SAND SIMULATION

Dames & Moore

ATTACHMENT A-1

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U.S. GEOLOGICAL SURVEY MODULAR FINITE-DIFFERENCE GROUND-WATER MODEL


Maryland Sand, Gravel, and Stone Site (MSGS)
   1 LAYERS        32 ROWS        32 COLUMNS
  1 STRESS PERIOD(S) IN SIMULATION
MODEL TIME UNIT IS DAYS

I/O UNITS:
ELEMENT OF IUNIT:  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
        I/O UNIT: 10  0  0  0  0  0  0  0 13  0  0 14  0  0  0  0  0  0  0  0  0  0  0  0

BAS1 -- BASIC MODEL PACKAGE, VERSION 1, 9/1/87 INPUT READ FROM UNIT  1
ARRAYS RHS AND BUFF WILL SHARE MEMORY.
START HEAD WILL BE SAVED
    9204 ELEMENTS IN X ARRAY ARE USED BY BAS
    9204 ELEMENTS OF X ARRAY USED OUT OF   30000

BCF1 -- BLOCK-CENTERED FLOW PACKAGE, VERSION 1, 9/1/87 INPUT READ FROM UNIT 10
STEADY-STATE SIMULATION
CELL-BY-CELL FLOWS WILL BE RECORDED ON UNIT 31
     LAYER  AQUIFER TYPE
     -------------------
       1        0
      1 ELEMENTS IN X ARRAY ARE USED BY BCF
    9205 ELEMENTS OF X ARRAY USED OUT OF   30000

SIP1 -- STRONGLY IMPLICIT PROCEDURE SOLUTION PACKAGE, VERSION 1, 9/1/87 INPUT READ FROM UNIT 13
MAXIMUM OF  50 ITERATIONS ALLOWED FOR CLOSURE
 5 ITERATION PARAMETERS
    4301 ELEMENTS IN X ARRAY ARE USED BY SIP
   13506 ELEMENTS OF X ARRAY USED OUT OF   30000
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BOUNDARY ARRAY FOR LAYER 1 WILL BE READ ON UNIT 81 USING FORMAT: (40I2)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
2	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
3	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
4	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
5	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
6	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
7	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
8	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
9	-1	1	1	1	1	1	1	1	1	1	1	1	1	$\boxed{-1}$ Well	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
10	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
11	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
12	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	$\boxed{-1}$ Well	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
13	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
14	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
15	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	$\boxed{-1}$ Well	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
16	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
17	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
18	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
19	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
20	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
21	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
22	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
23	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
24	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1

Note: "-1" indicates constant-head cell
"1" indicates a normal cell

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
25	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
26	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
27	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
28	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
29	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
30	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
31	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
32	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1

AQUIFER HEAD WILL BE SET TO .00000 AT ALL NO-FLOW NODES (IBOUND=0). ← No no-flow cells

INITIAL HEAD FOR LAYER 1 WILL BE READ ON UNIT [illegible] USING FORMAT: (40F2.0)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] Well	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]								
12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	$\boxed{70.}$ Well	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]								
13	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]								
14	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]								
15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	$\boxed{70.}$ Well	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]								
16	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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17	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]								
18	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]								
19	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]								
20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]								
21	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]								
22	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]								
23	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]								
24	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]								
25	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]								
26	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]								
27	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]								
28	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]								
29	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]								
30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

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      00. 00. 00. 00. 00. 00. 00. 00. 00. 00. 00. 00.

 31   00. 00. 00. 00. 00. 00. 00. 00. 00. 00. 00. 00. 00. 00. 00. 00. 00. 00. 00. 00.
      00. 00. 00. 00. 00. 00. 00. 00. 00. 00. 00. 00.

 32   00. 00. 00. 00. 00. 00. 00. 00. 00. 00. 00. 00. 00. 00. 00. 00. 00. 00. 00. 00.
      00. 00. 00. 00. 00. 00. 00. 00. 00. 00. 00. 00.

HEAD PRINT FORMAT IS FORMAT NUMBER -8    DRAWDOWN PRINT FORMAT IS FORMAT NUMBER -8

HEADS WILL BE SAVED ON UNIT 0    DRAWDOWNS WILL BE SAVED ON UNIT 32

OUTPUT CONTROL IS SPECIFIED EVERY TIME STEP

                                  COLUMN TO ROW ANISOTROPY =  1.000000

                                                     DELR =  135.1400

                                                     DELC =  135.1400

                              TRANSMIS. ALONG ROWS =  1.150000    FOR LAYER 1
```

i.e., Transmissivity is the same along rows and columns

Cell dimensions

```
                              SOLUTION BY THE STRONGLY IMPLICIT PROCEDURE
                              -------------------------------------------

                      MAXIMUM ITERATIONS ALLOWED FOR CLOSURE =      50
                                      ACCELERATION PARAMETER =     1.0000
                          HEAD CHANGE CRITERION FOR CLOSURE =     .10000E+00
                          SIP HEAD CHANGE PRINTOUT INTERVAL =       1

 5 ITERATION PARAMETERS CALCULATED FROM SPECIFIED WSEED =  .0010000 :

       .0000000E+00   .8221720E+00   .9683772E+00   .9943766E+00   .9990000E+00
```

Interval details of calculations - not hydrogeologic parameters

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STRESS PERIOD NO. 1, LENGTH = 1000.000

NUMBER OF TIME STEPS = 1

MULTIPLIER FOR DELT = 1.000

INITIAL TIME STEP SIZE = 1000.000

Ignored, since simulation is steady-state

10 ITERATIONS FOR TIME STEP 1 IN STRESS PERIOD 1

MAXIMUM HEAD CHANGE FOR EACH ITERATION:

HEAD CHANGE	LAYER,ROW,COL	HEAD CHANGE	LAYER,ROW,COL	HEAD CHANGE	LAYER,ROW,COL	HEAD CHANGE	LAYER,ROW,COL	HEAD CHANGE	LAYER,ROW,COL
-4.603	(1, 13, 18)	-2.765	(1, 13, 16)	-2.076	(1, 12, 13)	-2.197	(1, 17, 20)	-1.222	(1, 19, 12)
-.2590	(1, 11, 20)	.2725	(1, 22, 15)	.2243	(1, 22, 16)	.3791	(1, 19, 13)	.9032E-01	(1, 20, 25)

HEAD/DRAWDOWN PRINTOUT FLAG = 1 TOTAL BUDGET PRINTOUT FLAG = 0 CELL-BY-CELL FLOW TERM FLAG = 1

OUTPUT FLAGS FOR ALL LAYERS ARE THE SAME:

HEAD PRINTOUT	DRAWDOWN PRINTOUT	HEAD SAVE	DRAWDOWN SAVE
0	1	1	0

" CONSTANT HEAD" BUDGET VALUES WILL BE SAVED ON UNIT 31 AT END OF TIME STEP 1, STRESS PERIOD 1
"FLOW RIGHT FACE " BUDGET VALUES WILL BE SAVED ON UNIT 31 AT END OF TIME STEP 1, STRESS PERIOD 1
"FLOW FRONT FACE " BUDGET VALUES WILL BE SAVED ON UNIT 31 AT END OF TIME STEP 1, STRESS PERIOD 1

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DRAWDOWN IN LAYER 1 AT END OF TIME STEP 1 IN STRESS PERIOD 1

Zero because border cells are constant-head

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
2	.0	.0	.1	.1	.2	.3	.3	.4	.4	.5	.6	.6	.7	.7	.7	.7	.7	.6	.6	.5
3	.0	.1	.2	.3	.4	.5	.6	.7	.9	1.0	1.1	1.2	1.3	1.4	1.4	1.4	1.4	1.3	1.2	1.1
4	.0	.1	.3	.4	.6	.7	.9	1.1	1.3	1.5	1.7	1.9	2.1	2.2	2.2	2.1	2.1	1.9	1.8	1.7
5	.0	.2	.4	.6	.8	1.0	1.2	1.5	1.7	2.0	2.3	2.6	2.8	3.0	3.0	2.9	2.8	2.6	2.4	2.2
6	.0	.2	.4	.7	.9	1.2	1.5	1.8	2.1	2.5	2.9	3.3	3.7	3.9	3.9	3.8	3.6	3.3	3.1	2.8
7	.0	.3	.5	.8	1.1	1.4	1.7	2.1	2.5	3.0	3.5	4.1	4.7	5.1	5.0	4.7	4.4	4.1	3.7	3.4
8	.0	.3	.6	.9	1.2	1.5	1.9	2.3	2.8	3.4	4.0	4.8	5.8	6.8	6.3	5.7	5.2	4.8	4.4	4.0
9	.0	.3	.6	.9	1.3	1.7	2.1	2.5	3.0	3.7	4.4	5.4	7.0	$\boxed{.0}$ Well	7.3	6.6	6.0	5.6	5.1	4.5
10	.0	.3	.7	1.0	1.4	1.7	2.2	2.6	3.2	3.8	4.6	5.5	6.6	7.7	7.3	7.0	6.7	6.3	5.8	5.1
11	.0	.3	.7	1.0	1.4	1.8	2.2	2.7	3.3	3.9	4.6	5.3	6.2	6.9	7.1	7.3	7.5	7.6	6.7	5.7
12	.0	.3	.7	1.0	1.4	1.8	2.3	2.7	3.2	3.8	4.5	5.2	5.9	6.5	7.0	7.5	8.3	$\boxed{.0}$ Well	7.5	6.1
13	.0	.3	.7	1.0	1.4	1.8	2.2	2.7	3.2	3.7	4.3	4.9	5.6	6.2	6.9	7.3	8.1	8.3	7.2	6.1
14	.0	.3	.7	1.0	1.4	1.8	2.2	2.6	3.1	3.6	4.1	4.7	5.3	6.0	6.7	7.6	8.4	7.8	6.9	5.9
15	.0	.3	.7	1.0	1.4	1.7	2.1	2.5	3.0	3.4	3.9	4.5	5.0	5.7	6.5	7.7	$\boxed{.0}$ Well	7.7	6.5	5.6
16	.0	.3	.6	1.0	1.3	1.7	2.0	2.4	2.8	3.2	3.7	4.2	4.7	5.2	5.9	6.6	7.3	6.6	5.9	5.2
17	.0	.3	.6	.9	1.3	1.6	1.9	2.3	2.6	3.0	3.4	3.8	4.2	4.7	5.2	5.6	5.8	5.6	5.2	4.7
18	.0	.3	.6	.9	1.2	1.5	1.8	2.1	2.4	2.8	3.1	3.5	3.8	4.2	4.5	4.8	4.9	4.8	4.5	4.2
19	.0	.3	.6	.8	1.1	1.4	1.7	1.9	2.2	2.5	2.8	3.1	3.4	3.7	3.9	4.1	4.2	4.1	3.9	3.7
20	.0	.3	.5	.8	1.0	1.3	1.5	1.8	2.0	2.3	2.5	2.8	3.0	3.2	3.4	3.6	3.6	3.5	3.4	3.2
21	.0	.2	.5	.7	.9	1.2	1.4	1.6	1.8	2.1	2.3	2.5	2.7	2.9	3.0	3.1	3.1	3.1	3.0	2.8
22	.0	.2	.4	.6	.8	1.1	1.3	1.4	1.6	1.8	2.0	2.2	2.4	2.5	2.6	2.7	2.7	2.6	2.6	2.4
23	.0	.2	.4	.6	.8	.9	1.1	1.3	1.5	1.6	1.8	1.9	2.1	2.2	2.3	2.3	2.3	2.3	2.2	2.1
24	.0	.2	.3	.5	.7	.8	1.0	1.1	1.3	1.4	1.6	1.7	1.8	1.9	1.9	2.0	2.0	1.9	1.9	1.8
25	.0	.1	.3	.4	.6	.7	.9	1.0	1.1	1.2	1.4	1.5	1.5	1.6	1.6	1.7	1.6	1.6	1.6	1.5
26	.0	.1	.2	.4	.5	.6	.7	.8	1.0	1.1	1.1	1.2	1.3	1.3	1.4	1.4	1.4	1.3	1.3	1.2

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27	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0	1.0	1.1	1.1	1.1	1.1	1.1	1.1	1.0	1.0
28	.0	.1	.2	.2	.3	.4	.5	.6	.6	.7	.8	.8	.8	.9	.9	.9	.9	.8	.8	.8
29	.0	.1	.1	.2	.2	.3	.4	.4	.5	.5	.6	.6	.6	.6	.6	.6	.6	.6	.6	.6
30	.0	.0	.1	.1	.2	.2	.2	.3	.3	.3	.4	.4	.4	.4	.4	.4	.4	.4	.4	.4
31	.0	.0	.0	.1	.1	.1	.1	.1	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2
32	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

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DRAWDOWN IN LAYER 1 AT END OF TIME STEP 1 IN STRESS PERIOD 1

	21	22	23	24	25	26	27	28	29	30	31	32
1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
2	.5	.4	.4	.3	.3	.2	.2	.2	.1	.1	.0	.0
3	1.0	.9	.8	.7	.6	.5	.4	.3	.2	.2	.1	.0
4	1.5	1.3	1.2	1.0	.9	.7	.6	.5	.4	.2	.1	.0
5	2.0	1.8	1.6	1.4	1.2	1.0	.8	.6	.5	.3	.2	.0
6	2.5	2.2	1.9	1.7	1.4	1.2	1.0	.8	.6	.4	.2	.0
7	3.0	2.7	2.3	2.0	1.7	1.4	1.2	.9	.7	.5	.2	.0
8	3.5	3.1	2.7	2.3	1.9	1.6	1.3	1.0	.8	.5	.3	.0
9	4.0	3.5	3.0	2.6	2.2	1.8	1.5	1.1	.8	.6	.3	.0
10	4.4	3.8	3.3	2.8	2.4	2.0	1.6	1.2	.9	.6	.3	.0
11	4.8	4.1	3.5	3.0	2.5	2.1	1.7	1.3	1.0	.6	.3	.0
12	5.1	4.3	3.7	3.1	2.6	2.2	1.7	1.4	1.0	.6	.3	.0
13	5.2	4.4	3.7	3.2	2.7	2.2	1.8	1.4	1.0	.7	.3	.0
14	5.1	4.3	3.7	3.2	2.7	2.2	1.8	1.4	1.0	.7	.3	.0
15	4.9	4.2	3.6	3.1	2.6	2.1	1.7	1.3	1.0	.6	.3	.0
16	4.6	4.0	3.5	3.0	2.5	2.1	1.7	1.3	1.0	.6	.3	.0
17	4.2	3.7	3.2	2.8	2.4	2.0	1.6	1.2	.9	.6	.3	.0
18	3.8	3.4	3.0	2.6	2.2	1.8	1.5	1.2	.9	.6	.3	.0
19	3.4	3.1	2.7	2.4	2.0	1.7	1.4	1.1	.8	.6	.3	.0
20	3.0	2.7	2.4	2.1	1.9	1.6	1.3	1.0	.8	.5	.3	.0
21	2.6	2.4	2.2	1.9	1.7	1.4	1.2	1.0	.7	.5	.2	.0
22	2.3	2.1	1.9	1.7	1.5	1.3	1.1	.9	.7	.4	.2	.0
23	2.0	1.8	1.7	1.5	1.3	1.2	1.0	.8	.6	.4	.2	.0
24	1.7	1.5	1.4	1.3	1.2	1.0	.9	.7	.5	.4	.2	.0
25	1.4	1.3	1.2	1.1	1.0	.9	.7	.6	.5	.3	.2	.0
26	1.2	1.1	1.0	.9	.8	.7	.6	.5	.4	.3	.1	.0

27	1.0	.9	.8	.8	.7	.6	.5	.4	.3	.2	.1	.0
28	.8	.7	.7	.6	.5	.5	.4	.3	.3	.2	.1	.0
29	.6	.5	.5	.4	.4	.4	.3	.2	.2	.1	.1	.0
30	.4	.3	.3	.3	.3	.2	.2	.2	.1	.1	.0	.0
31	.2	.2	.2	.1	.1	.1	.1	.1	.1	.0	.0	.0
32	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 1 IN STRESS PERIOD 1

CUMULATIVE VOLUMES	L**3	RATES FOR THIS TIME STEP	L**3/T
IN:		IN:	
STORAGE =	.00000	STORAGE =	.00000
CONSTANT HEAD =	28420.	CONSTANT HEAD =	28.420
TOTAL IN =	28420.	TOTAL IN =	28.420
OUT:		OUT:	
STORAGE =	.00000	STORAGE =	.00000
CONSTANT HEAD =	28544.	CONSTANT HEAD =	28.544
TOTAL OUT =	28544.	TOTAL OUT =	28.544
IN - OUT =	-124.17	IN - OUT =	-.12417
PERCENT DISCREPANCY =	-.44	PERCENT DISCREPANCY =	-.44

TIME SUMMARY AT END OF TIME STEP 1 IN STRESS PERIOD 1

	SECONDS	MINUTES	HOURS	DAYS	YEARS
TIME STEP LENGTH	.864000E+08	.144000E+07	24000.0	1000.00	2.73785
STRESS PERIOD TIME	.864000E+08	.144000E+07	24000.0	1000.00	2.73785
TOTAL SIMULATION TIME	.864000E+08	.144000E+07	24000.0	1000.00	2.73785

These lengths of time are not meaningful, since the simulation is steady-state. The simulation represents drawdown after a long enough time that water levels have stabilized, and at all subsequent times.

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